# TRANSACTIONS

OF THE

# ROYAL SOCIETY OF SOUTH AFRICA.

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WITH FOURTEEN PLATES.

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VOL. XXVII.

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# SOME DESMIDS FROM THE TRANSVAAL.

By Florence Rich.*

(Communicated by E. L. Stephens.)

(With three Text-figures.)

(Read April 20, 1938.)

## Introduction.

Algae from the Belfast Pan in the Transvaal were examined by the writer and Professor F. E. Fritsch, F.R.S., from collections made in 1909, 1913, and 1924 by Dr. E. M. Doidge (Principal Plant Pathologist in the Division of Plant Industry, Pretoria). Accompanying the samples collected by her in 1924 were two tubes containing algae from other localities in the neighbourhood, one (Tube 1141) about two miles away, and the other (Tube 1142) four miles. At the time of our investigation, however, we decided to confine our attention to the Pan itself, so that the list we published in 1937 represents that piece of water only. The Belfast Pan was found to be rich in algal life, especially in Desmids, of which twenty-one genera were represented, and nearly a hundred and fifty species and varieties; fourteen of the species and twenty-five varieties were new to science, not having been previously described. The Pan is an isolated stretch of water, and the new forms and varieties there found may have originated from introduced individuals under the influence of the special habitat

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conditions obtaining there. It is not at all likely that these new Desmids are confined to the Belfast Pan, and it therefore seemed of interest to examine the contents of the two additional tubes in order to determine if any of them were present there. It now appears that although nearly seventy species and varieties of Desmids (belonging to ten genera) are present in these tubes, there is not, as far as observation goes, a single individual belonging to any of the new species or varieties.

The two additional collections differ from those from the Pan in being made from running water, and therefore from localities not so suitable to the growth of Desmids, which are usually free-floating plants favouring still water, although a certain number are known to be met with among submerged plants in slow streams and rivers (W. and G. S. West, 1904, p. 13).

The contents of the tubes are as follows:—

*Tube* 1141. January 22, 1924.—From the stems of water plants (including *Nitella*) in running water in a vlei (*i.e.* an expanse of flat marshy ground with one or more streams running through it), near the Forestry Station, about two miles from the Belfast Pan, and on lower ground. In addition to about fifty species of Desmids, members of the following genera were found: *Pediastrum*, *Scenedesmus*, *Coleochaete*, *Aphanochaete*, *Microspora*, *Oedogonium*, *Bulbochaete*, *Spirogyra*, *Zygnema*, *Gomphonema*, *Synedra*, *Cymbella*, *Navicula*, *Eunotia*, *Nitzschia*, *Euglena*, *Phacus*, *Lepocinclis*, and *Trachelomonas*.

*Tube* 1142. January 22, 1924.—From small streams trickling into a little river (a tributary of the Elands River), near the Drift (ford), three or four miles to the east of the Belfast Pan, on the opposite side of a small range of hills. In addition to nearly twenty-five species of Desmids, members of the following genera were found: *Ankistrodesmus*, *Hormidium*, *Ulothrix*, *Stigeoclonium*, *Mougeotia*, *Spirogyra*, *Navicula*, *Gomphonema*, *Eunotia*, *Oscillatoria*, and *Cylindrospermum*.

Thus, though both tubes contain Desmids and Diatoms, only Tube 1141 contains Flagellates, and only Tube 1142 Blue-Greens, and it is apparent that the contents of the two vary very considerably. The Desmids present are for the most part different, only nine species being common to the two tubes. Of the Desmids recorded from Belfast Pan sixteen species and varieties were observed in Tube 1141 and seven in Tube 1142. The only Desmids common to all three pieces of water were: *Netrium digitus*, *Closterium Knysnanum*, *Euastrum insulare*, and *Cosmarium asymmetricum*. Most of the Desmids found are of common occurrence, but as there are a few not previously recorded from South Africa it seems desirable to publish a complete list of such as lend themselves to identification.

The following is a brief comparison between the streams and the Belfast Pan:—

Of the genus *Netrium* the widely distributed *N. digitus*, as mentioned before, was present in the Pan and in both streams.

Two species of *Penium* were found in the Pan; a different one in each of the two streams.

Nine species of *Closterium* were present in the Pan, and twelve (mostly different) in the streams.

Seventeen species of *Euastrum* occurred in the Pan, of which the cosmopolitan *E. denticulatum*, *E. elegans*, and *E. insulare* were also found in the streams, together with four others.

Five species of *Micrasterias* were found in the Pan, and four in the streams.

Only nine of nearly fifty species of *Cosmarium* occurring in the Pan were found in the streams, and there were about twelve others, most of them of world-wide distribution.

Nine or ten species of *Staurastrum* were found in the streams, nearly all of them different from those in the Pan.

Filamentous Desmids, which were rather abundant in the Pan, were rare in the streams; only traces of a species of *Hyalotheca* and of *Desmidium* were found in Tube 1141.

New varieties are described of *Cosmarium granatum*, *Cosmarium sulcatum*, and *Staurastrum disputatum*, and several new *formae*.

Attention should be drawn to the occurrence of the little-known *Staurastrum franconicum*.

## Systematic Enumeration of the Desmids found.

(References to existing figures are given when they represent well the Desmid recorded.)

### Genus Netrium Naegeli.

*Netrium digitus* (Ehrenb.) Itzigs. and Rothe.

Long. cell., 130–340 $\mu$; lat., 38–95 $\mu$.

Present in Tubes 1141 and 1142, and also in Belfast Pan.

var. *latum* Hustedt, 1911, p. 314, fig. 5.

Long. cell., 120 $\mu$; lat., 60 $\mu$. This is smaller than Hustedt's variety, but the proportions are exactly the same.

Tube 1142.

*Netrium Nägelii* (Bréb.) W. and G. S. West, 1904, p. 66, pl. vii, fig. 4.

Long. cell., 29–35 $\mu$; lat., 115–132 $\mu$.

Tube 1142.

## Genus PENIUM de Brébisson.

*Penium cylindrus* (Ehr.) Ralfs; W. and G. S. West, 1904, p. 84, pl. vi, fig. 2.

Cell-wall dark brown in colour, furnished with minute scattered granules.

Tube 1142.

*Penium margaritaceum* (Ehr.) Bréb.

Long. cell., 80–90 $\mu$; lat., 20 $\mu$.

There is a distinct median constriction, and the wall is furnished with longitudinal rows of granules.

Tube 1141.

var. *obesum* Cushman.

Long. cell., 52–66 $\mu$; lat., 20 $\mu$.

The rows of granules, except just near the poles, are fused to form longitudinal striae.

Shorter, and relatively stouter, than the type.

Tube 1141.

Not previously recorded from S. Africa.

## Genus CLOSTERIUM Nitzsch.

? *Closterium acerosum* (Schrank) Ehrenb.

Long. cell., 400 $\mu$; lat., 30 $\mu$.

Cell-wall brown, striolate, but near the apices faintly granulate.

Tube 1141. Very few individuals seen.

*Closterium Cornu* Ehrenb. (Fig. 1, G.)

Long. cell., 112 $\mu$; lat., 8 $\mu$.

Tube 1141.

I think this is a new record for S. Africa.

? *Closterium Cynthia* De Not.

Dist. inter apic., 76–86 $\mu$; lat., 12–13 $\mu$.

Cell-wall yellow and striolate; one moving granule. (The girdle-band was not observed.)

Tube 1141.

*Closterium Dianae* Ehrenb. *formae :*

(*a*) Approaching the type (W. and G. S. West, 1904, pl. xv, figs. 1, 5).

Dist. inter apic., 120–124 $\mu$; lat. 16 $\mu$. The curvature of the outer margin is about 130° of arc, the inner margin not tumid. The dorsal margin at each apex is obliquely truncate and thickened. Cell-wall colourless. The individuals observed seem to be intermediate between the type and var. *arcuatum* (Bréb.) Rabenh.

Tube 1141. Another form was present in Belfast Pan.

(*b*) *Forma* Krieger, 1932, p. 160, pl. iii, fig. 17.

Dist. inter apic., 80 $\mu$; lat., 9 $\mu$. The curvature of the outer margin is about 120° of arc.

I should have ascribed the specimens I found to a variety of *Cl. parvulum* Naeg. were it not for the apices of the cells which were characteristic of *Cl. Dianae*. Krieger, *loc. cit.*, mentions a form coming in dimensions very near that now under consideration.

Tube 1141.

*Closterium Ehrenbergii* Menegh.

Long. cell., 560 $\mu$; lat., 100 $\mu$.

Tube 1141.

*Closterium gracile* Bréb.

Long. cell., 204 $\mu$; lat., 4 $\mu$.

Tube 1141. Also present in Belfast Pan. This Desmid seems to be common in Africa.

*Closterium Knysnanum* Huber-Pestalozzi, 1930, p. 471.

Long. cell., 183–230 $\mu$; lat., 25–30 $\mu$; lat. apic., 12–13 $\mu$.

There were about seventeen striae visible across the middle of the cell. The apices of some individuals showed the darker coloration noted by Huber-Pestalozzi in his original description.

Tubes 1141 and 1142. In Belfast Pan was a forma *major*.

*Closterium Libellula* (Focke) Nordst. (Syn. *Penium Libellula*) var. *intermedium* Roy and Biss.

Long. cell., 83–126 $\mu$; lat., 20–28 $\mu$.

Tube 1142. The type is known from the Orange River and from Stellenbosch.

var. *interruptum* W. and G. S. West; Krieger, 1932, p. 162, pl. v, fig. 4.

Long. cell., 106–120 $\mu$; lat., 27 $\mu$.

Tube 1142.

*Closterium Malinvernianum* De Not.

Dist. inter apic., 320 $\mu$; lat., 54 $\mu$.

Tube 1141.

*forma* approaching f. *major* Fritsch, 1917, p. 544.

Dist. inter apic., 360 $\mu$; lat., 90 $\mu$. The cell-wall is yellow and finely striolate. It is wider than the type, but is not so large as the form found by Fritsch in the Cape Peninsula.

Tube 1141.

*Closterium rostratum* Ehrenb.

Dist. inter apic., 240–250 $\mu$; lat., 19–20 $\mu$.

Cell-wall yellow or brown; apices of extremities very slightly dilated.

Tube 1142. Known from South Africa. The allied species *Cl. setaceum* Ehrenb. is present in Belfast Pan.

*Closterium spetsbergense* Borge, 1911, p. 8, fig. 5.

Long. cell., 320–360 μ; lat., 58–60 μ. One row of pyrenoids, of which there are about 8 in each semicell.

Tube 1142.

*Closterium Venus* Kütz.

Dist. inter apic., 50 μ; lat., 8·5 μ. Like other specimens found in S. Africa there was only one moving granule in the terminal vacuole.

Tube 1141. Known from S. Africa.

### Genus Pleurotaenium Naegeli.

*Pleurotaenium Trabecula* (Ehrenb.) Naeg.

Long. cell., 72·5 μ; lat., 23 μ.

Tube 1141.

### Genus Euastrum Ehrenberg.

*Euastrum ansatum* Ralfs var. *dideltiforme* Ducell., 1918, p. 42, fig. 17.

Long. cell., 80 μ; lat., 40 μ.

Very similar to the form figured by Ducellier, but a little smaller.

Tube 1141.

*Euastrum denticulatum* (Kirchn.) Gray *forma* Fritsch and Rich, 1937, fig. 5, F–H.

Long. cell., 23–24 μ; lat., 17–18 μ.

Tube 1141. Present in Belfast Pan.

*Euastrum elegans* (Bréb.) Kütz. var. *madagascariense* West; Rich, 1932, p. 167, fig. 6, C.

Long. cell., 25 μ; lat., 19 μ.

Somewhat similar to the specimens found in Belfast Pan, but more closely resembling those in Old Ngamo (Rich, 1935, p. 131).

Tube 1141. Present in Belfast Pan.

*Euastrum insulare* (Wittr.) Roy.

Long. cell., 28–30 μ; lat., 18–20 μ.

Tube 1142, precisely similar to the individuals found in Belfast Pan.

*forma* W. and G. S. West, 1905, p. 69, pl. xl, fig. 14.

Long. cell., 21–23 μ; lat., 15–16 μ; isthm., 4–5 μ.

In outline exactly like the form found by the Messrs. West in Cambridgeshire.

Tube 1141.

*Euastrum sinuosum* Lenorm. var. *reductum* W. and G. S. West *forma.* (Fig. 1, A.)

Long. cell., 52–58 $\mu$; lat., 32–34 $\mu$. It shows the slight indentation on the lateral lobes indicated in the drawings by Prescott and a few other observers.

Tube 1142. Not previously known from S. Africa.

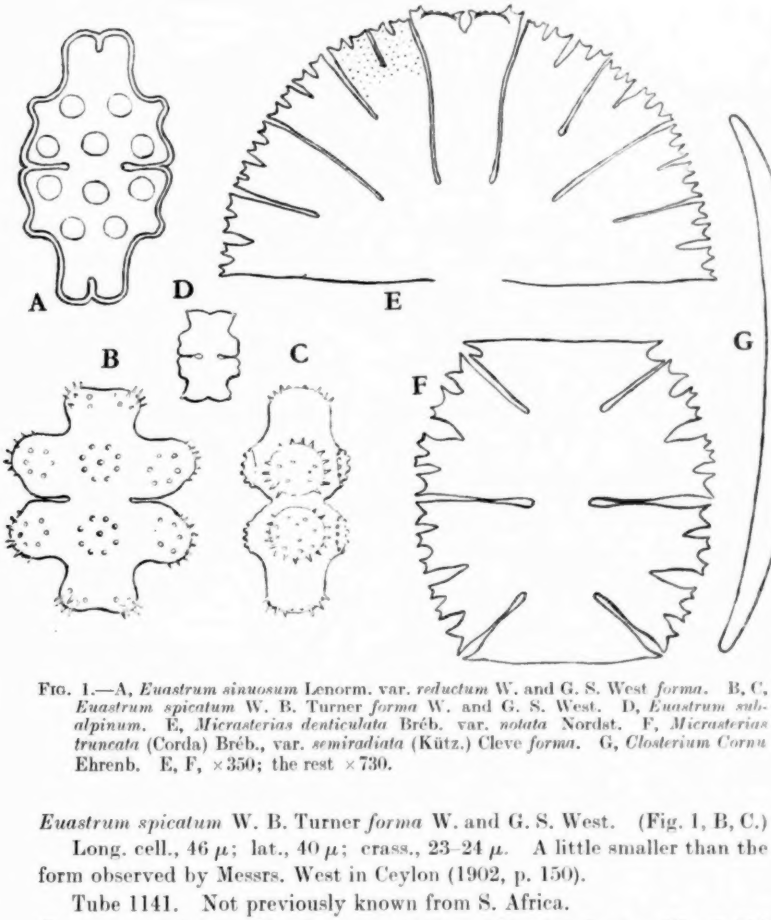


FIG. 1.—A, *Euastrum sinuosum* Lenorm. var. *reductum* W. and G. S. West *forma.* B, C, *Euastrum spicatum* W. B. Turner *forma* W. and G. S. West. D, *Euastrum subalpinum.* E, *Micrasterias denticulata* Bréb. var. *notata* Nordst. F, *Micrasterias truncata* (Corda) Bréb., var. *semiradiata* (Kütz.) Cleve *forma.* G, *Closterium Cornu* Ehrenb. E, F, ×350; the rest ×730.

*Euastrum spicatum* W. B. Turner *forma* W. and G. S. West. (Fig. 1, B, C.)

Long. cell., 46 $\mu$; lat., 40 $\mu$; crass., 23–24 $\mu$. A little smaller than the form observed by Messrs. West in Ceylon (1902, p. 150).

Tube 1141. Not previously known from S. Africa.

*Euastrum sabalpinum* Messikommer, 1935, p. 120, pl. i, fig. 5. (Fig. 1, D.)

Long. cell., 18–20 $\mu$; lat., 13–14 $\mu$; isthm., 4·5 $\mu$. A very small

*Euastrum* resembling *E. insulare*, but characterized by its slightly dilated apex, and a minute papilla terminating the upper angle on each side in the front view.

Tube 1142. Not previously recorded for S. Africa.

Genus Micrasterias Agardh.

*Micrasterias crux-melitensis* (Ehrenb.) Hass. var. *evoluta* W. B. Turner.

Long. cell. (max.), 88–90 $\mu$; lat., 84 $\mu$; isthm., 15 $\mu$.

Tube 1141. Another variety was present in Belfast Pan.

*Micrasterias decemdentata* (Naeg.) Arch. *forma*.

Similar to some of the forms found in Natal (Fritsch and Rich, 1924, p. 337).

Tube 1142. Present in Belfast Pan.

*Micrasterias denticulata* Bréb., var. *notata* Nordst. (Syn. *M. angulosa* Hantzsch var. *notata* Nordst.). (Fig. 1, E.)

Long. cell., 228–240 $\mu$; lat., 190–204 $\mu$; isthm., 25–26 $\mu$.

Cell-wall coarsely punctate.

Tubes 1141, 1142.

*Micrasterias truncata* (Corda) Bréb. var. *semiradiata* (Kütz.) Cleve *forma*. (Fig. 1, F.)

Long. cell., 130–134 $\mu$; lat., 140 $\mu$. The cells are usually a little wider than long. This form resembles var. *africanum* Fritsch and Rich in its deep incision on either side of the polar lobe.

Tube 1142.

Genus Cosmarium Corda.

*Cosmarium amoenum* Bréb. (Fig. 2, A.)

Long. cell., 50–56 $\mu$; lat., 28–30 $\mu$; isthm., 19 $\mu$; crass., 26 $\mu$.

There are about 9 vertical series of granules visible across the face of the semicell; two pyrenoids in each semicell. The sinus is variable. This is a widely distributed Desmid, though not a common one. It has not previously been recorded for S. Africa. The rather similar *C. pseudamoenum* is also present.

Tube 1141. Not previously recorded from S. Africa.

*Cosmarium asymmetricum* Rich, 1935, p. 132, fig. 10, D.

Long. cell., 19–22 $\mu$; lat., 16–20 $\mu$; isthm., 4–5 $\mu$. A little larger than the specimens found in Southern Rhodesia, but very similar indeed to those in Belfast Pan.

Tubes 1141 and 1142.

*Cosmarium binum* Nordst.

Long. cell., 54–64 $\mu$; lat., 40–48 $\mu$; isthm., 15–16 $\mu$; crass., 29 $\mu$.

In most individuals there was a single series of rounded granules just beneath the central tumour, in others there was a double series.

Tubes 1141 and 1142.

*Cosmarium Blytii* Wille.

Long. cell., 16 $\mu$; lat., 14 $\mu$.

Tube 1141. Present in Belfast Pan.

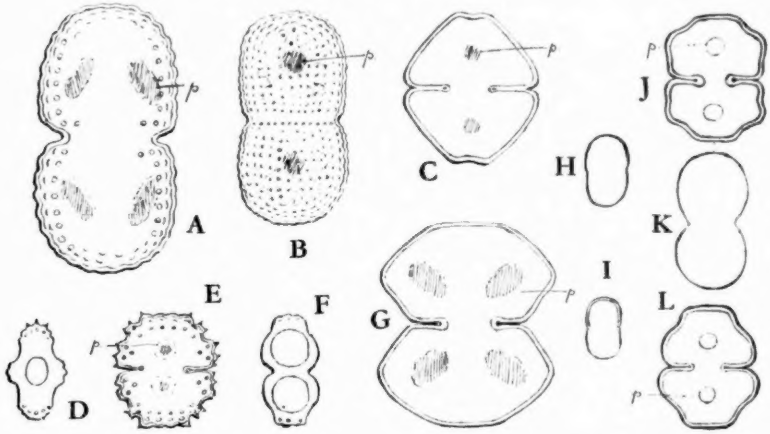


FIG. 2.—A, *Cosmarium amoenum* Bréb. B, *C. pseudamoenum* Wille. C, *C. granatum* Bréb. var. nov. *latum*. D–F, *C. subprotumidum* Nordst. var. *Gregorii* (Roy and Biss.), W. and G. S. West. G, *C. sulcatum* Nordst. var. nov. *compressum*. H–I, *C. pseudarctoun* Nordst. forma. J, K, *C. Hammeri* var. *africanum* forma. L, *C. Hammeri* var. *protuberans* (?) forma. *p*, pyrenoid.

*Cosmarium cucurbita* Bréb.

Long. cell., 32 $\mu$; lat., 20 $\mu$.

Tube 1142. Present in Belfast Pan.

*Cosmarium granatum* Bréb. var. nov. *latum*. (Fig. 2, C.)

Cellulae leviter longiorae quam latae, penitus constrictae; sinu angusto lineari cum apice vix dilato; semi-cellulae truncatae-pyramidiformae; angulis basalibus rotundatis-subrectangularibus, apice angusto truncato retuso.

Long. cell., 29–30 $\mu$; lat., 26–28 $\mu$; isthm., 8–9 $\mu$.

Cells very little longer than broad, deeply constricted, sinus narrowly linear with scarcely dilated apex; semicells truncate pyramidate; basal angles rounded-subrectangular; apex narrowly truncate, retuse. This

variety comes near var. *africanum* Fritsch, but it is proportionately wider, and consequently more flattened in appearance. The dimensions come within the range of those of the type (W. and G. S. West, 1905, p. 187), but the general appearance is different.

Tube 1141.

*Cosmarium Hammeri* Reinsch var. *africanum* Fritsch *forma* Fritsch and Rich, 1937, fig. 14, C. (Fig. 2, J, K.)

Long. cell., 26–29 μ; lat., 21–24 μ; isthm., 6–7 μ; crass., 15 μ.

The lower parts of the lateral margins are almost subparallel. In its general shape in front view it resembles *C. repandum* Nordst., but differs from that species in possessing only one pyrenoid per semicell.

Tube 1141. Also present in Belfast Pan.

? var. *protuberans* W. and G. S. West *forma*. (Fig. 2, L.)

Long. cell., 23–24 μ; lat., 18–20·5 μ; isthm., 6·5–7 μ.

The apex is broad and very slightly retuse. (The vertical view was not seen.)

Tube 1141. Present, though not recorded, in Belfast Pan.

This species is common in S. Africa and is very variable.

*Cosmarium impressulum* Elfv. *forma* Hodgetts, 1925, p. 80, fig. 10.

Long. cell., 28 μ; lat., 21 μ; isthm., 5–6 μ.

Margin markedly 8-undulate; the second undulation from the sinus is more prominent than in the type.

Tube 1141.

*Cosmarium laeve* Rab. var. *pseudo-octangularis* Fritsch and Rich, 1929, p. 60.

Long. cell., 21 μ; lat., 16 μ.

The lower lateral margins are more or less markedly divergent, and the apex is slightly retuse, as in Griqualand West.

Tube 1141. The type was present in Belfast Pan.

? *Cosmarium margaritatum* (Lund) Roy and Biss. forma *minor* Boldt.

Long. cell., 50 μ; lat., 40 μ; isthm., 13–14 μ.

The punctulations between the granules were not observed.

Tube 1141.

*Cosmarium pseudamoenum* Wille. (Fig. 2, B.)

Long. cell., 41–46 μ; lat., 22–25 μ; isthm., 19–20 μ.

Cell-wall uniformly granulate; one pyrenoid in each semicell. Cells not so deeply constricted as in *C. amoenum*, otherwise very like this species, which is also present in the same sample. Messrs. W. and G. S. West (1911, p. 31) say that the distinctions between *C. pseud-*

*amoenum* and *C. amoenum* are very slight, hence it is interesting to find both species present together.

Tube 1141.

*Cosmarium pseudarctoum* Nordst. *forma*; W. and G. S. West, 1908, p. 32. (Fig. 2, H–I.)

Long. cell., 12–14 $\mu$; lat., 8 $\mu$. One of the smaller *forma* of this species; the lateral margins are nearly parallel.

Tubes 1141 and 1142.

*Cosmarium pseudopyramidatum* Lund. *forma.*

Long. cell., 56–57 $\mu$; lat., 38 $\mu$; isthm., 10–11 $\mu$.

There is one pyrenoid, and the surface is scrobiculate. It is a little larger than the type, but not so big as var. *maximum* Boergesen. Very similar to the forms seen in Belfast Pan.

Tube 1142.

*Cosmarium punctulatum* Bréb. var. *subpunctulatum* (Nordst.) Boerg.; W. and G. S. West, 1908, p. 209, pl. lxxxiv, fig. 19.

Long. cell., 23–24 $\mu$; lat., 20–23 $\mu$; isthm., 7–8 $\mu$. The apex of the semicell is granulate. The dimensions are a little less than those given for the variety by Messrs. West, but are similar to those found in other South African individuals. It is closely allied to *C. anisochondrum* Nordst., in which species, however, the constriction is deeper, and the isthmus consequently narrower, and the basal angles of the semicell are more rectangular.

Tube 1141.

*Cosmarium Regnesi* Reinsch var. *montanum* Schmidle.

Long. cell., 13 $\mu$; lat., 12 $\mu$; isthm., 5–6 $\mu$.

Tube 1141. The type was present in Belfast Pan.

*Cosmarium sexangulare* Lund. forma *minima* Nordst.

Long. cell., 12–14 $\mu$; lat., 11–12 $\mu$; isthm., 3–4 $\mu$.

Tube 1141.

*Cosmarium subcrenatum* Hantzsch.

Long. cell., 23–24 $\mu$; lat., 20–23 $\mu$; isthm., 11 $\mu$.

Sides 5-crenate, apex 4-crenate.

Tube 1141. Present in Belfast Pan.

*Cosmarium subprotumidum* Nordst.

Long. cell., 22–24 $\mu$; lat., 21 $\mu$; isthm., 6 $\mu$; crass., 13–14 $\mu$.

An abnormality similar to that observed in Kentani (Fritsch and Stephens, 1921, p. 41) and in Griqualand West (Fritsch and Rich, not recorded) was present.

Tube 1141.

var. *Gregorii* (Roy and Biss.) W. and G. S. West. (Fig. 2, D–F.)

Long. cell., 22–27 μ; lat., 20–23 μ; isthm., 6 μ; crass., 12–13 μ.

Lateral crenations distinctly bigranulate. Marginal granules conical in form.

Tube 1141.

*Cosmarium sulcatum* Nordst. var. nov. *compressum*. (Fig. 2, G.)

Sinus pro longitudine majore quam ad typus clausus; cellulae depressae, ad perpendiculum directus complanatae, videuntur.

Long. cell., 40–44 μ; lat., 31–40 μ; isthm., 9–11 μ; crass., 24–25 μ.

The semicells in front view are widest across the middle, and the apex is truncate; in both these respects there is a resemblance to *C. sulcatum*, but the sinus is closed for a longer distance, thus giving the cells a more (horizontally) compressed appearance. The surface is scrobiculate, and there are two pyrenoids in each semicell. The chloroplasts are axile with radial extensions. In his original description Nordstedt (1878, p. 13) gives no dimensions, and is not sure about the number of pyrenoids.

In some of the forms, presumably belonging to this variety (long. cell., 36–37 μ; lat., 30–31 μ; isthm., 7–9 μ), there is a distinct resemblance to *C. subtumidum* Nordst., especially to Taylor's figure of this species (1934, pl. 1, fig. 3), and there is also an agreement in dimensions.

Tube 1141.

*Cosmarium tetragonum* Naeg.; W. and G. S. West, 1908, p. 17, pl. lxvi, fig. 20.

Long. cell., 36 μ; lat., 33 μ.

Tube 1141.

Genus Staurastrum Meyen.

*Staurastrum alternans* Bréb.

Long. cell., 21–22 μ; lat., 22–24 μ; isthm., 5–6 μ. Sinus open and acute-angled.

Tubes 1141 and 1142.

*Staurastrum dilatatum* Ehrenb.

Long. cell., 22–30 μ; lat., 24–28 μ; isthm., 8–9 μ.

Tubes 1141 and 1142.

*Staurastrum disputatum* Ehrenb. (Syn. *S. dilatatum* var. *insigne* Racib.) var. nov. *annulatum*. (Fig. 3, A–B.)

Semicellulae in parte basali fere brevae-cylindriformae. Granuli in series quater circa angulos dispositi, cum circulo granulorum circa 24 supra isthmum proximo. A vertice visis 4-radiantae.

The arms of one semicell alternate with those of the other, as often happens in *Staurastrum*. It resembles both var. *extensum* (Borge) W. and G. S. West (1911, p. 177) and var. *sinense* (Lutkem.) W. and G. S. West, but is larger, and the ring of about 24 granules just

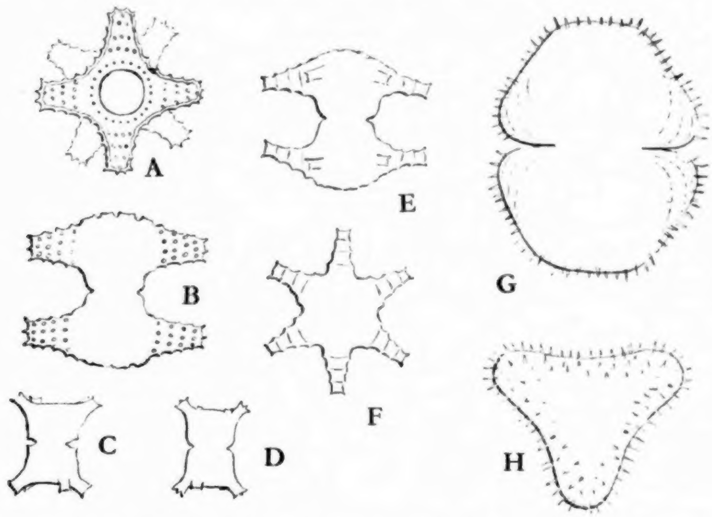


FIG. 3.—A, B, *Staurastrum disputatum* Ehr. var. *annulatum* Rich. C, D, *Staurastrum franconicum* Reinsch *forma nov.* E, F, *Staurastrum gracile* Ralfs var. *nanum* Wille *forma nov.* G, H, *Staurastrum subbrebissonii* Schmidle var. or f.

above the isthmus marks it out from all other forms that have been described.

Tube 1142. The type is known from West Africa, and var. *sinense* from Central Africa.

*Staurastrum franconicum* Reinsch *forma nov.* (Fig. 3, C, D.)

Long. cell. (sine proc.), 16–17 $\mu$; lat. (cum proc.), 18–20 $\mu$; isthm., 6–7 $\mu$. This is a very small *Staurastrum* with four arms, each ending in two or three teeth. The sinus consists of a minute excavation in the middle of the cell; the apex and lateral margins are nearly straight. In one individual there was observed a minute tooth at the lower end of the lateral margin on each side. It shows certain resemblances to *S. rectangulare* Borge and *S. zonatum* Borge.

*S. franconicum* is not at all well known. The original drawings of Reinsch (Die Algenflora des mittleren Theiles von Frankau, 1867, pl. xii, fig. 3) are not very satisfactory, and I cannot find any figures that have

been published since his time. Wolle (Desmids of the United States, 1884, pl. xlii, figs. 47–50) gives drawings of *S. pusillum* (Wolle), a species which he describes as being very like *S. franconicum*, but differing from it in being somewhat smaller and having four instead of five processes, very unimportant differences.

*S. pusillum* seems to me in no way to differ from Reinsch's diagnosis of *S. franconicum*, and I do not feel this species can stand.

(The forms described by Wolle were all granular, but I have failed to see any granules in those now under investigation.)

Tube 1141. Very rare indeed. Not previously recorded for South Africa.

*Staurastrum gracile* Ralfs var. *nanum* Wille *forma nov.* (Fig. 3, E, F.)

Long. cell., 28–30 μ; lat., 31–35 μ; isthm., 8–9 μ. The apex is convex, and there are six arms.

Tube 1141. Zygospores of what is presumably the type were found in Belfast Pan.

*Staurastrum orbiculare* Ralfs var. *depressum* Roy and Biss.

Long. cell., 24 μ; lat., 24–27 μ; isthm., 7 μ.

Tube 1141.

*Staurastrum polymorphum* Bréb.; West and Carter, 1923, p. 125, pl. cxliii, fig. 3, *a* and *b*.

Long. cell., 23 μ; lat., 22–24 μ; isthm., 7–8 μ. Processes short and stout, slightly incurved, tipped with three spines, and provided with three series of minute denticulations. A small and very variable species, with an almost world-wide distribution.

Tube 1141.

*Staurastrum spongiosum* Bréb.; West and Carter, 1923, p. 76. Var.

Long. cell. (sine proc.), 34 μ; lat., 34 μ; isthm., *circa* 16 μ. Not nearly so deeply constricted as the type, and probably approaching var. *cumbricum* Bennet, a variety insufficiently described. The numerous verrucae are large enough almost to constitute short processes with emarginate apices. Only a few individuals were seen, and it was not found possible to make a satisfactory drawing. The determination must remain vague.

Tube 1141.

*Staurastrum subbrebissonii* Schmidle, approaching var. *hexagonum* Gutwinski. (Fig. 3, G, H.)

Long. cell., ad 52 μ; lat., 40–46 μ. Covered with longish spines. Vertical view triangular.

Tubes 1141 and 1142. Very few individuals seen.

### Genus HYALOTHECA Ehrenberg.

*Hyalotheca dissiliens* (Sm.) Bréb.

Long. cell., 18 $\mu$; lat., 17 $\mu$.

Tube 1141.

### Genus DESMIDIUM Agardh.

*Desmidium Swartzii* Ag.

Long. cell., 20 $\mu$; lat., 35 $\mu$.

Tube 1141.

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# STUDIES IN SOUTH AFRICAN RICCIACEAE.

## II. The Annual Species of the Section Ricciella (concluded): *R. compacta* sp. nov., and *R. Rautanenii* Steph.

By A. V. Duthie and S. Garside.

(With Plate I and twenty-six Text-figures.)

(Read July 20, 1938. Revised MS. received December 12, 1938.)

Since the publication of the first of our "Studies in South African Ricciaceae," in which *R. Curtisii* was fully described, it has been possible to examine in greater detail the "thalli—more compact in texture and lacking the gaping air-chambers of the usual form" which are there mentioned (I, p. 128). We now find that these belong, not to *R. Curtisii*, but to a distinct species having synsporous spores and in other respects also closely allied to that plant. The occurrence of the new species growing side by side with thalli of typical *R. Curtisii* precludes the possibility of the two being epharmonic forms.

### *Riccia compacta* Garside (sp. nov.).

*Figures.*—Figs. 1–6 and Plate I, fig. 6.

*Exsic.*—Duthie 5418, Stellenbosch, near the University Library. Aug.–Oct. 1937. 5486, Platklip, Stellenbosch, on granitic sand. Sept. 1938.

Annua, dioica; frons femina flavovirens, semiorbicularis vel orbicularis ut plurimum 8–10 mm. lata, semel vel bis lobato divisa, cavernosa, cavernae angustae, 12 fere in frondis diametro una serie dispositae; nullae squamae ventrales; capsulae uniseriatim immersae, sporae luteo-brunnae, maturitate conjunctae, tetradae 100–120 $\mu$ diam., extus papillatae, papillis obtusis, simplicibus vel saepe bifidis, reticulum basilare imperfectum.

Frons mascula purpurea, orbicularis, 6–8 mm. lata, fronde bis-ter dichotomo-divisa, ostiolis antheridiorum hyalinis.

Annual, dioecious. Isolated female thalli semi-orbicular, 8–10 mm. diam., two or three times dichotomously branched, bright green,* concolorous below, or when crowded and overlapping forming rosettes up to 16 mm. diam. Apex rounded, slightly emarginate, dorsal surface almost plane, crystalline, and marked with polygonal areas, air-pores

* Colour of female thalli and of apices of lobes of male thalli, taken with R. Ridgway's "Color Standards and Color Nomenclature," Lettuce Green or Cosse Green.

inconspicuous. Older portions of the thallus becoming pitted as the result of enlargement of air-pores. Transverse section of female thallus twice as broad as high, dorsal surface almost plane, ventral surface very convex, bearing tuberculate and smooth rhizoids in almost equal numbers. Air-chambers narrow, about twelve across the section, in a single layer. Basal tissue scanty, ventral scales absent. Archegonial neck at maturity $300\,\mu$ long, the lower half becoming purple after fertilisation. Sporangia in a single series in the median line, not crowded. Spores yellowish brown, more or less translucent, permanently adhering in tetrads which are $100$–$120\,\mu$ in diameter, convex faces with crowded spines, which are cylindrical or slightly flattened and have truncate simple or slightly bifid apices. Spines longest in the centre of each convex face, becoming gradually shorter towards the periphery, where they are reduced to small warts. Some of the longer spines are confluent at their bases or throughout the entire length. The bases of the spines are joined here and there by low ridges, forming an incomplete reticulum which is usually most conspicuous where the spines are longest, but disappears towards the periphery of each convex face.

Male thalli generally deep purple-brown, with the margins paler, when growing isolated, forming rosettes up to 8 mm. in diameter, the branches being crowded, and two or three times dichotomously divided. Small purple or green male thalli are frequently found intermingled with groups of female thalli. Very small air-chambers occur on the dorsal surface, but the internal tissues consist of large, thin-walled cells. Ventral scales absent, tuberculate and smooth rhizoids abundant. Ostioles irregularly disposed in the median line, hyaline.

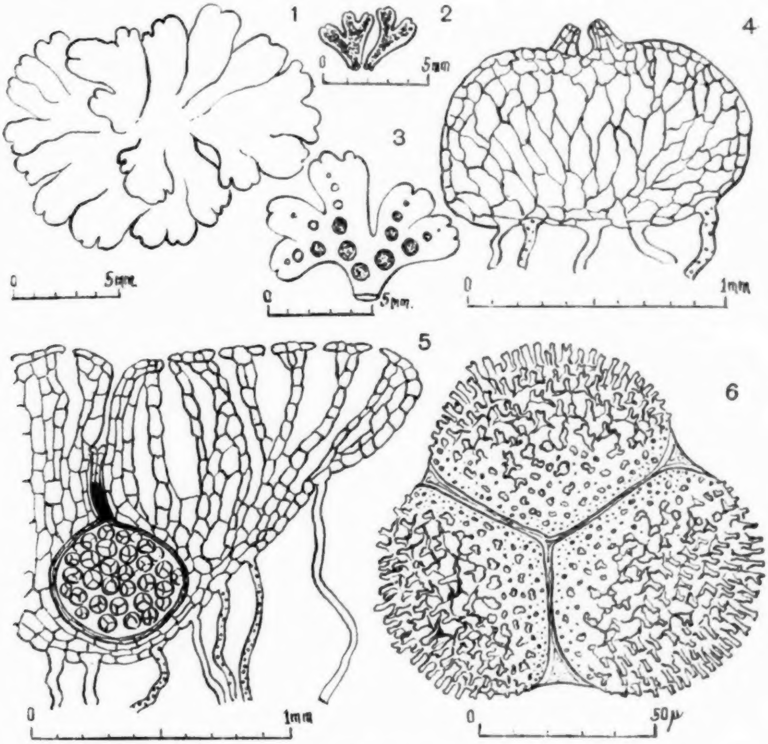
The above description is based on Duthie 5418.

This species was first recognised as distinct when it was observed growing among sparse grass, near the University Library, Stellenbosch, closely associated with *R. cupulifera* and with the spongy thalli of *R. Curtisii*. It was kept under observation during the months of August, September, and October 1937.

In colour and texture the female thallus differs considerably from that of *R. Curtisii*, of which species we had at first considered it to be only a variety, and bears a superficial resemblance to the female thallus of *R. cupulifera*. One must frequently rely upon spore differences to separate immature female thalli of *R. compacta* and *R. cupulifera*. The associated male thalli, which are usually dull purple in colour, but may also be green, are often of a relatively large size, and closely resemble those of *R. Curtisii*. As in *R. Curtisii*, reduced and stunted male thalli may often be found intermingled with large rosettes of female plants (Plate I, fig. 6); but the species is at once distinguished from the latter species by the firmer and more compact nature of the air-chamber layer. Plate I, fig. 7, shows two female thalli of *R. Curtisii* and two of *R. compacta*, which were growing close together under identical conditions. The contrast between the loose, open texture of the air-chamber layer in the former and the solid-looking and comparatively unpitted surface of the latter is obvious. Thus *R. compacta* is certainly not a growth-form of *R. Curtisii*, but a distinct

species, as is also indicated by the presence of well-marked tuberculate rhizoids and characteristic spore markings.

The possibility that *R. compacta* may be of hybrid origin is indicated by the combination of such characters as the copious tuberculate rhizoids,




*R. compacta*, figs. 1–6. All drawn from Duthie 5418.

FIG. 1.—A large female thallus.
FIG. 2.—Branches of a male thallus.
FIG. 3.—Branches of a small female thallus, showing position of sporangia.
FIG. 4.—Transverse section of a male thallus, showing two ostioles.
FIG. 5.—Transverse section of a female thallus, with a young sporangium.
FIG. 6.—A spore tetrad.

the colour, texture, and surface areolae of the female thallus, the presence of shallow depressions above the archegonia and young sporogonia, and the occurrence of the sporogonia along the middle line of the lobe—all of which suggest *R. cupulifera*—with the adherent spores and general type of spore-

marking of *R. Curtisii*; in addition to its close association with the presumed parents in the field. The purple colour of the male thalli when strongly illuminated is yet another character which *R. compacta* shares with *R. Curtisii*. All three species are annual and dioecious.

Immature female thalli which resembled the Stellenbosch material of *R. compacta* very closely were found near Darling in the Malmesbury District on 11th September 1937, associated with large numbers of typical thalli of *R. cupulifera*.

Schiffner (4) has recently described two forms of *R. Curtisii*, a lax plant, *fo. tenuis*, and a rosette-forming plant, *fo. crassior*, which he considers to be epharmones. His conclusions were based on herbarium material only, from America. In South Africa we have examined much material of *R. Curtisii* growing under natural conditions, but having failed to find anything approaching the range of form described by Schiffner, we are forced to conclude that the *fo. laxa* is in fact a true species, still awaiting fuller investigation in the field. We have already suggested the possible occurrence of two species of synsporous Ricciae in North America (1, p. 130).

The Section Thallocarpus of the genus *Riccia* recently proposed by Schiffner (4), and which now contains *R. synspora* Schiffner (Brazil), *R. Curtisii* T. P. James (America and South Africa), and the species here described, *R. compacta* Garside (South Africa), is a very natural one, the species included in it having many other points in common in addition to synspory; *e.g.* the dioecious habit, the great difference in size of the male and female thalli, spore markings of a similar type, and, so far as known, the annual habit. The two other sections of the genus, Ricciella and Euriccia, are probably quite artificial, and fuller descriptions of both structure and life-history will be required before it will be possible to formulate more natural groupings.

### *Riccia Rautanenii* Steph.

*Riccia Rautanenii* Steph., Bull. Herb. Boiss., vi, 378, 1898.
*Ricciella Rautanenii* Steph., Bull. Herb. Boiss., iii, 374, 1895.
*Ricciella Rautanenii* Steph., Cat. Welwitch. Afr., pl. ii, 311, 1895.

*Type.*—"Africa occidentalis in Herero prope Usab in alveo fluminis Tsoachaub, ad terram leg. M. Rautanen." (Bull. Herb. Boiss., iii, 374, 1895.)

We have not seen the type, which is in the Zürich Herbarium, but we have examined the plants from the River Bero, near Cavallieros, Mossamedes, collected by Dr. Welwitch, July 1857, and determined by Stephani.

*Figures.*—Figs. 7–26 and Pl. I, figs. 1–5.

*Exsic.*—The following are A. V. Duthie's herbarium numbers:—

*Cape Province.*—5009, Orange River, near Kakamas, July–Sept. 1929 and 1930. 5059, Jenkin's Sloot, Cradock District, on mud at edge of river pools, July 9, 1930. 5070, Dwyka, in drying stream-bed, Sept. 1930. 5130, Orange River, five miles from Upington,

Sept. 1932. 5144, Brak River, Doornberg, Middelberg, C.P., on mud among Phragmites stems, July 1931. 5300, Orange River, near Upington, July 1935. 5301, Orange River, near Kakamas, July 1935. 5312, Orange River, near Upington, Sept. 1935. 5399, Herbert Division, June 1937. 5405, near Calitzdorp, July 1937. 5411, Bedford, Aug. 1937.

*Transvaal.*—5395, Limpopo River, July 1935.

*Portuguese East Africa.*—5311, Olifant's River, tributary of the Limpopo at Massengiri, Aug. 1935. 5326, same locality as 5311, Oct. 1935.

*South-West Africa.*—5186, Aus, on river sand, Aug. 1934. 5416, near Windhoek, mud of delta of stream flowing into Avis Dam, July 7, 1937.

*Northern Rhodesia.*—5314, Zambezi River, on mud, July 1930.

*Southern Rhodesia.*—5071, Umzingwani, in river bed, July 1930.

Most of the above have been collected by friends, to whom the thanks of the authors are due.

We have examined the following exsiccata:—

Welwitch, Iter Benguellense, No. 257, "River Bero, near Cavallieros, Mossamedes, July 1857." (In British Museum.)

The following material in South African herbaria has also been examined. In some cases the material was fragmentary, but the spore-markings agree closely with the material described by us (Duthie 5009). Garabedian, river bed, Umzingwani, S. Rhodesia, July 1930 (in S.A. Museum Herbarium); Barnard, Aughrabies Falls, July 1925 (in S.A. Museum Herbarium); Esterhuysen, Herbert Division, June 1937 (McGregor Museum); Wager, Bulawayo (in Cryptogamic Herbarium, Pretoria); Burtt Davy, Vereeniging, Transvaal, Oct. 1914 (in Cryptogamic Herbarium, Pretoria); Junod, P.E. Africa (in Cryptogamic Herbarium, Pretoria); Junod, Lourenço Marques, P.E. Africa, March 1919 (in Cryptogamic Herbarium, Pretoria); Garabedian, S. Rhodesia, July 1930 (in Cryptogamic Herbarium, Pretoria); Wager, George, 1917 (in Cryptogamic Herbarium, Pretoria).

Annual, monoecious, forming very regular or rarely irregular rosettes up to 3 cm. or more in diameter. Lobes repeatedly dichotomously branched, overlapping laterally; pale green and solid when young, and remaining green or becoming reddish and spongy with age, the reddish colour appearing on the thallus margins and around the archegonial pits; dorsal surface minutely crystalline due to the presence of scattered, convex, light-reflecting cells, and in older parts marked with numerous shallow depressions or pits indicating the positions of the sex organs. Mature thallus in section about 2·5 mm. thick, with one layer of narrow air-chambers situated upon a shallow basal tissue of about 4–6 cells thick, the cell walls of this tissue having very numerous slit-like pits which are best developed below the maturing sporangia. Chlorophyll most abundant in the plates of cells separating the air-chambers, and in the outer layer of the venter before the spores mature, but also present in some degree in the basal tissues, with the exception of the rhizogenous lower epidermis. No storage starch is present in the basal tissues. The ventral surface of the thallus is entirely and very closely attached to the substratum by very numerous tuberculate and smooth rhizoids, which are crowded, long, and often very much distorted. No ventral or apical scales can be detected.

Both antheridia and archegonia occur abundantly in separate pits scattered throughout the mature portions of the thallus.

Antheridia small, deeply embedded, the colourless ostiole 400–500 $\mu$ long, projecting from a pit.

Archegonia very numerous, each one deeply sunk in a pit, so that the apex of the colourless neck may be 1 mm. below the thallus surface. Mature archegonium neck

250–350 $\mu$ long, becoming brown after fertilisation. Sporangia very numerous in all parts of the thallus, and usually so crowded that, when mature, they displace and crush the air-chambers, and themselves often become deformed because of mutual pressure. Sporangia 1 mm. to ·8 mm. diameter, but when crowded they are often elongated, being 1 mm. long and from ·5 mm. to ·8 mm. wide. Spores separating at maturity, angular, dark brown, almost opaque, and very variable in size and markings, even in the same sporangium. Spore diameter 80–120 $\mu$. Outer face very convex, with thick, raised ridges forming areolae which are larger in the centre, where they frequently become incomplete, so that the centre of the face is marked with 3 or 4 prominent radiating ridges.

Margin with a small, irregularly erose and finely crenate wing, 5–6 $\mu$ wide; marginal angles entire. Inner faces plane, with numerous short sinuous, simple, or branched raised ridges, which are sometimes well developed and unite into areolae, or they are reduced to short unbranched ridges and tubercles. Triradiate marking of three stout single, or rarely double ridges, almost always confluent at the apex, rarely incomplete. The triradiate ridges extend at the marginal angles to the edge of the wing, and are therefore visible from the outer face of the spore.

Spores from undersized sporangia smaller, 62–82 $\mu$, less dense but with the wing proportionately larger. Outer face with areolae much broken and often reduced to ridges only.

The above description is based on Duthie 5009.

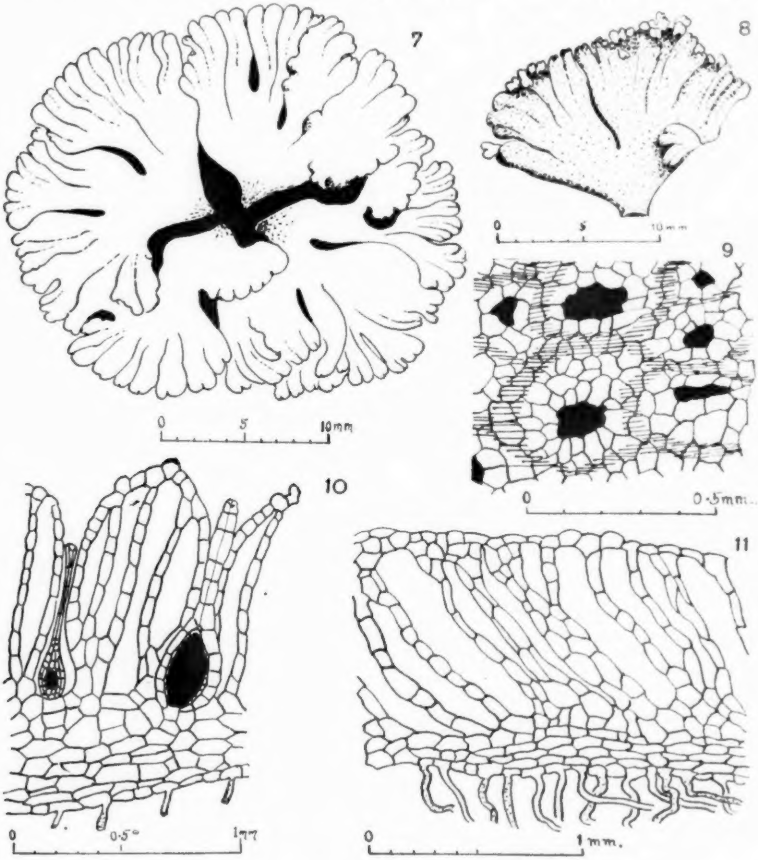
*Riccia Rautanenii* was discovered by M. Rautanen growing in the bed of the River Tsoachaub in Hereroland. It was later found by Dr. Welwich in the littoral region of the plain of Mossamedes, and also in muddy places by the banks of the River Bero, in Angola, but since these collections were made very little additional material has been brought to Europe.

Being a very conspicuous species, forming massive rosettes which occur in large numbers, it is well calculated to attract the attention of collectors, and several South African Herbaria contain specimens of the plant, usually incorrectly labelled "*R. crystallina* L.", this, doubtless, because the younger thalli have some resemblance to the European plant which passes under this name.

The material we have studied has been collected on alluvial mud or sand, along the banks of the Orange River, chiefly from the two localities, Kakamas and Upington, but in addition we have examined specimens from South-West Africa (Aus), Rhodesia, Portuguese East Africa, and from Cradock and the Middelburg District, C.P., so that we may conclude that the species has a wide distribution across the southern portion of Africa. With the exception of Wager's fragmentary material from George, we have seen no examples from the coastal districts of the Cape Province, and it is probable that the plant is absent from the area of winter rainfall.

*R. Rautanenii* is an annual which, when the water-level is falling, appears upon the mud flats of river beds, where the thallus rapidly matures its spores. Later, when the mud is completely dry, the thallus disintegrates, liberating numerous spores which are distributed along the river bed during

subsequent flooding. Much of our material has been obtained from areas which would be completely submerged when the river is full. The very




*R. Rautanenii*, figs. 7–11.

FIG. 7.—A large thallus (Duthie 5009).
FIG. 8.—Portion of a thallus, showing the production of new branches after cultivation for several months in shade (Duthie 5009).
FIG. 9.—Air-pores in surface view.
FIG. 10.—Transverse section of thallus, showing an archegonium and an antheridium (Duthie 5300).
FIG. 11.—Longitudinal section of a thallus, showing air-chambers (Duthie 5009).

large number of sporangia and spores formed by the thallus increases the chance of survival in the precarious habitat in which the plant lives.

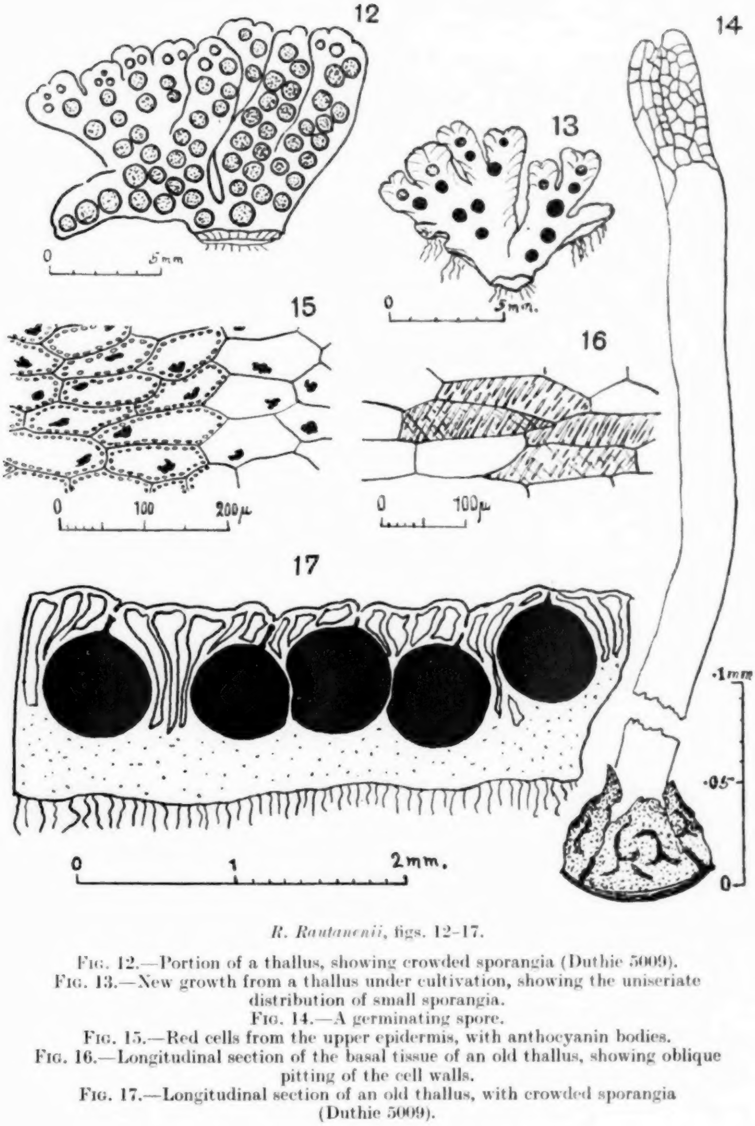
When mature plants taken from their natural habitat (Plate I, fig. 1) are protected from drought, and cultivated under moist-shaded conditions, the life of the thallus can be considerably prolonged, and subsequent growth results in a remarkable change in its appearance. In about four months under such conditions (August to November 1935, for Duthie 5300) the margins and dorsal surface of the old thallus produced numerous adventitious new growths (fig. 8, and Plate I, fig. 3), which later develop into pale-green narrow cylindrical or flattened dichotomous branches, which completely cover the old thallus in about nine months, become anchored to the soil by smooth rhizoids, and may even be fertile, producing small undersized sporangia (·3–·5 mm. diam.), arranged in a single row in the median line (fig. 13, and Plate I, figs. 4 and 5). The spores in these sporangia are smaller than normal, being 62–82 $\mu$ in diameter, and with a more or less incomplete reticulum on the convex face (figs. 20, 23, and 26).

The adventitious branches which result from prolonged growth in the shade have no trace of the red coloration which is a common feature of the thalli from which they arise, and they differ also in producing smooth rhizoids only. They have, however, well-formed air-chambers. Such adventitious branching is rarely seen in the natural habitat, and the production of these small thallus lobes is thus probably not a natural mode of vegetative propagation, but merely the result of abnormal conditions. Indeed, no vegetative means of passing through a period of drought has been observed, and under natural conditions the beginning of the dry season terminates the life of all thalli, survival until the next season being effected by spores alone.

There are two characteristic features of cell-structure in this species which call for special attention. In plants grown under natural conditions, the margins of the thallus lobes and of the archegonial pits, or even the entire surface of the plant, may have a reddish-purple * tint. In liverworts, a purple coloration when present is usually in the cell-wall only, but here it is the cell-sap of the epidermal cells which has a pale pink colour, the walls being colourless. In addition to the green chloroplasts and the pink cell-sap, there is usually one deep reddish-purple solid anthocyanin body present in each epidermal cell of the tinted area (fig. 15). The development of anthocyanin in this species seems to be a direct result of exposure to light, though not all plants in natural conditions exhibit it, and it is completely absent from the adventitious branches grown in the shade which have already been described.

A second peculiarity of this plant is the presence of cells with elongated

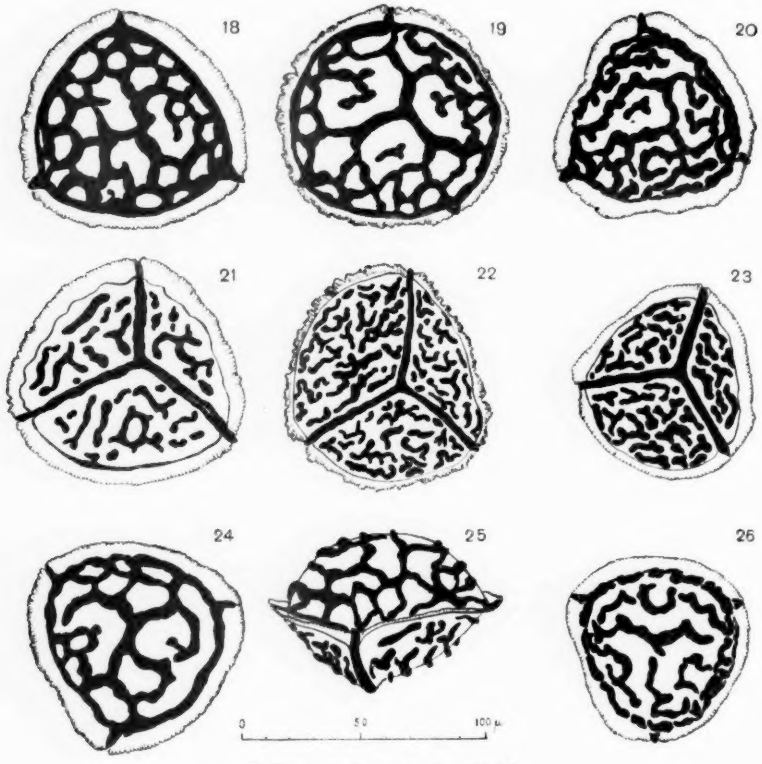
* Colour, taken with R. Ridgway's "Color Standards and Color Nomenclature," Amaranth Purple or Bordeau.




*R. Rautanenii*, figs. 12–17.

Fig. 12.—Portion of a thallus, showing crowded sporangia (Duthie 5009).
Fig. 13.—New growth from a thallus under cultivation, showing the uniseriate distribution of small sporangia.
Fig. 14.—A germinating spore.
Fig. 15.—Red cells from the upper epidermis, with anthocyanin bodies.
Fig. 16.—Longitudinal section of the basal tissue of an old thallus, showing oblique pitting of the cell walls.
Fig. 17.—Longitudinal section of an old thallus, with crowded sporangia (Duthie 5009).

slit-like pits in the basal tissues of the more mature portions of the thallus. They are best seen below the sporangia, where the pits are frequently so crowded on the cell-walls as to give the appearance of a reticulate thickening




*R. Rautanenii*, spores, figs. 18–26.

Figs. 18, 19, 24.—Outer faces of normal spores.
Figs. 20, 26.—Outer faces of spores from undersized sporangia.
Figs. 21, 22.—Inner faces of normal spores.
Fig. 23.—Inner face of a spore from an undersized sporangium.
Fig. 25.—Profile view of a normal spore.

Figs. 18, 21, 24, 25, from Duthie 5009; 19, 22, from Duthie 5301; 20, 23, 26, from Duthie 5300.

(fig. 16). Such pits have not previously been observed in any species of *Riccia*, but they are, of course, well known in the higher Marchantiaceae, and they have been described and figured for *Marchantia* by Strasburger (6) and van Tieghem (5), and for *Fegatella* by Müller (3) and Herzog (2).

Cultures of spores of various ages taken from living thalli were made in August 1929. By 5th October many of the more immature spores were found to have germinated, and some of these showed fairly advanced stages in segmentation of the germ-tube. The cultures were kept moist and shaded until the end of June 1930, when numbers of greatly elongated germ-tubes were noted, some of them 3 mm. in length. Many of these showed delayed segmentation of the apex of the germ-tube to organise the growing-point. The exit of the germ-tube was invariably on the convex or outer face of the spore (fig. 14).

Regarding the affinities of *R. Rautanenii*, the species is, undoubtedly, closely related to the recently described *R. robusta* Kashyap (Journ. Bombay Nat. Hist. Soc., xxiv, 348, 1916) which it closely resembles in habit, structure, and spore characters, though we do not consider the two species to be identical. In *R. robusta* the spores are almost devoid of wing, the ridges which form the markings on the spore are much finer and more delicate, and the reticulum on the outer face is very much broken. In size the spores of the two species are in agreement.

The plant known as *R. crystallina* L., from northern Europe (*e.g.* Gottsche et Rabenh. Hep. Eur. 370, 572; Rabenh. Hep. Eur. 66; Schiffner Hep. Eur. 2, 3; Migula Krypt. Ger. Aust. et Hung. 189), is also a related species, for although smaller, its thallus structure is similar and its spores have the same general type of marking. These three species, *R. Rautanenii*, *R. robusta*, and *R. crystallina* L., undoubtedly, form a very natural group to which the old name SPONGODES Nees (Nat. Eur. Leber., iv, 391, 1838, excl. *R. bullosa* Link) may be conveniently applied. If *R. Catalinae* Underwood and *R. Brandegei* Underwood from North America ultimately prove to be distinct from *R. crystallina* L., they must also be placed in this group.

*Errata.*

Studies in South African Ricciaceae. I. Three Annual Species, Trans. Royal Soc. S. Africa, vol. xxiv, 1936.

Page 116, line 20. For "5097" read "5007."

Page 129, line 1. For "antheridium" read "antheridial cavity."

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(4) SCHIFFNER, V., "Uber Thallocarpus Curtisii," Hedwigia, 76, pp. 140–152, 1936.

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## EXPLANATION OF PLATE.

1. *R. Rautanenii* Steph. Large thallus from mud along the Orange River, near Kakamas, about 50 yards from water's edge. Leg. P. C. van Dyk, 25th July 1935. (Duthie, 5301.)
2. Small thallus of *R. Rautanenii* Steph., from same locality as fig. 1.
3. *R. Rautanenii* Steph. Large thallus from Orange River, near Upington, cultivated under a bell-jar in greenhouse at Stellenbosch for about four months. Small new thalli are developing on the margins and on the surface of the old thallus. (Duthie, 5300.)
4. *R. Rautanenii* Steph. From the Orange River, near Upington. Leg. C. H. Schroder, 25th July 1935. Cultivated under a bell-jar in greenhouse until 5th April 1936. The old thallus is completely covered with a new growth of dichotomously branched narrow thalli.
5. *R. Rautanenii* Steph. As in fig. 4, but showing new growth developed from a small thallus similar to that in fig. 2.
6. *R. compacta* Garside. Three groups of female thalli and one isolated female thallus: also two large male thalli in conjunction. Stunted male thalli may be seen in the centres of the upper and lower groups of female thalli.
7. Thalli of *R. Curtisii* (above) growing beside female thalli of *R. compacta* Garside (below). From the College Campus, Stellenbosch. Leg. A. V. Duthie, September 1937.

The millimetre scale is for all the figures. Photographs from living plants by H. Herre, Stellenbosch.

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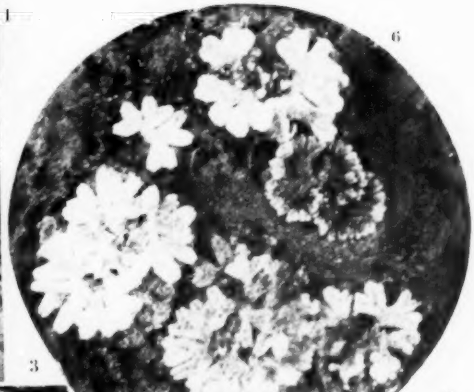

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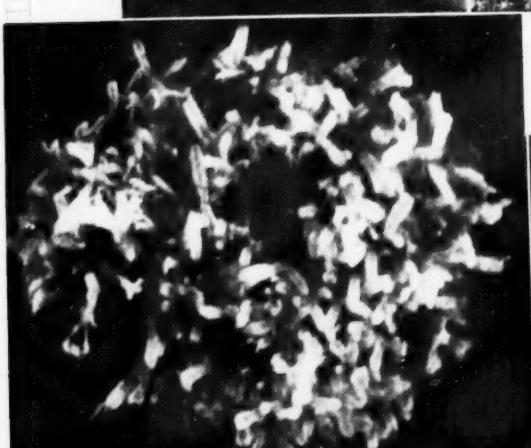

Figs. 1–5. *R. Rautanenii.*
Fig. 6. *R. compacta.*
Fig. 7. *R. Curtisii* (above).
*R. compacta* (below).

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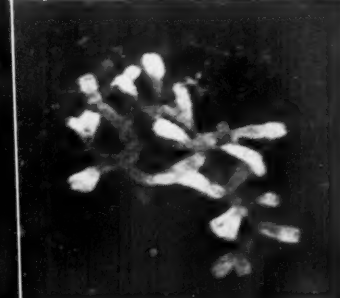


*Duthie and Garside.*

*Neill & Co., Ltd.*

# THE MORPHOLOGY AND CLASSIFICATION OF GROUND AND POLISHED STONE ARTEFACTS OF SOUTH AFRICAN ORIGIN.

By P. W. Laidler, F.S.A.Scot., F.R.A.I.

(With Plate II and one Text-figure.)

(Read August 17, 1938.)

The term "South African Neolithic" appears to be increasing in fashion, and those who use it appear to justify their doing so by the merely superficial resemblance between European and North African neolithic implements on the one hand, and South African ground or polished implements on the other; it is necessary, therefore, that all available evidence be gathered together, in order to prove or disprove the existence of any connection between these two sections, in technique, origin, or time period.

The term "neolithic" is used in Europe to denote a period during which man made pottery, possessed a knowledge of domesticated animals and agriculture. The people, with their culture, migrated from the Middle East, invading Europe, and displacing the Azilio-Tardenoisian civilisation, which was in South Africa practised by the Bushmen until a recent date (1). These neolithic culture people were not perpetual polishers, though their industry is characterised by a celt that has a flat axe-like edge, but tapers to a point at the butt end (1), in earlier days more or less circular on middle section, and towards the close of the period flatter and of finer finish. The neolithic age is well represented in North Africa.

The neolithic of the Fayum (2) is defined as the incipient knowledge of semi-civilised living, *i.e.* that the culture and methods are evolved, not imitated. The Fayum neolithic assemblage consists of concave base arrowheads, a widespread assortment of knives, ground axes of hard stone, crude pottery, and tanged arrowheads, and is dated at *circa* 5000 B.C. It possesses abundant evidences of agriculture.

Five distinct divisions are recorded in East Africa (3, p. 70), two of which belong to the Nakuran wet phase dated at 1000 to 850 B.C. Only one phase includes polished axes, of which fifteen were found, associated with pottery. It is suggested (3, p. 98) that the South African neolithic (that writer evidently accepting the undoubted existence of such a phase)

originates in influences or migrations emanating from the Tumbian area in the Congo, where axes and barbed arrowheads are associated.

Tumbian and the Gumban of East Africa (which possesses pottery) are considered to be contemporary, *circa* A.D. 850 or later, and contemporary with the metal age in the Mediterranean Basin.

## South African Records.

Dr. Atherstone in a notebook, dated September 1867 (Alb.), writes that he "picked up a stone arrowhead which had been evidently sharpened on a whetstone on both sides, picked up several fine ones evidently worked by hand without the conchoidal fracture." These are not now traceable.

Péringuey (4) in his chapter headed "Implements of European neolithic type" discussed pedunculated arrowheads from the Harrismith, O.F.S., area, and the very few-known flat stones with a ground edge. In each case the find was sporadic. The latter, he decided, were axes made from slabs of stone selected on account of their shape, rather than shaped by working. He would have welcomed any explanation of their presence, and appears to have concluded that neither these implements nor those of the Still Bay industry were worked by South African aboriginals. A later writer (5) considers the "introduction" of the polished "celt" and ornamented pottery to be the result of the North African neolithic culture meeting the Capsian. This theory of the origin of South African aboriginal pottery has been disposed of elsewhere (6). Goodwin and Lowe (7, p. 190) listing the complete assemblage of Smithfield B types include palettes and pottery, and state that the art of grinding edges appears then for the first time. Ground-edged artefacts are claimed by the former as neolithic elements in Transvaal and Rhodesia (8). Smithfield is assigned by Burkitt (9) to a perhaps ill-developed but definitely neolithic civilisation because of its querns, pottery, and polishing technique. The application of this term to the South African upper palaeolithic is considered unsafe by Neville Jones (10, p. 951). Breuil ascribes a ground "axe" to Wilton (11).

Dart and del Grande (12) state that "It is now generally recognised that there occur sporadically in Southern and Central Africa various polished celts." These investigators found three at Mumbwa in Northern Rhodesia, in a furnace stratum. One was compared by them with the Peddie specimen. They use the term neolithic while recording their belief that the idea of the Mumbwa axes was borrowed, and associate the ground-chopping edge with a "neolithic" metal-gaining people, and state that neolithic elements are a constituent part of our prehistory brought in from outside.

It appears, then, that though a majority accept the appearance of a grinding technique as evidence of the existence of a South African neolithic age, and are prepared to lay down its origin and line of migration, that a minority doubts it.

## Morphology and Typology.

Heese (13) discussing ground and polished implements from the North-West Karoo was the first to attempt a classification. He is, according to Goodwin (7), keen on the term "neolithic" being used to include all ground-stone work of human origin. Heese's list runs thus:

A. Implements with evidence of grinding, and in some instances of polishing, from open sites only.
  (i) A Jasper knife blade, chipped and ground.
  (ii) A knife of indurated shale 13 cm. × 4·1 × 1·3 ground to produce a cutting edge.
  (iii) A knife 64 × 20 × 4 cm. also ground to produce a cutting edge.
B. Scraper of slate, 7 mm. thick, a fragment only.
C. Palette of soft shale, one edge rounded, others sharp.
D. Stone rings or armlets.
E. Beads.
F. Polishing stones.

Heese is apparently inclined to class together all artefacts produced by rubbing or grinding. He does not suggest any age or period for this type of workmanship. Heese also classes the small beautiful tanged arrowheads found by him in the Britstown district as neolithic. Before proceeding to discuss this subject, the various polished and ground implements will be considered as types, with their distribution.

*Upper and Lower Grindstones.*—Those of Bushman origin vary in shape. The upper stones are usually pebbles of round, oval, or egg shape, of size to fit the one hand, with only the grinding face prepared for use and pitted near the centre—the remaining surface being original weathered-pebble cortex. The lower stones are ground and polished, only by action incidental to the work performed. We are not further concerned with these.

The Bantu millstone is large, about eighteen inches by twelve inches or more, and the upper stone, muller or rubber, is in modern days usually oval section, the larger surface being used. The Bantu grind with a rolling motion, both hands supinely gripping the grinder, pushing it away and over the material to be ground, at the end of the stroke flexing the wrist, and drawing the material towards the body. This motion gives a double-faceted shape to the muller, and produces a wide, extensive

hollow in the lower stone. Lower stones on ancient Bantu sites are so hollowed that they are in demand as bird baths, the *tsele* stones or mullers are circular, about four inches in diameter, frequently biface, each face with the double facet. Such biface *tsele* stones are characteristic of ancient Bantu settlements.

When the Bantu millstone needs sharpening, this is done by pecking the surface of the lower stone with the sharp edge of a broken stone.

A fragment of a large quern or millstone is at times used by the Bantu for snuff grinding, and such are distinctive by their small size, six to eight inches in diameter, and deep bowl. They are, of course, used with a smaller upper stone.

*The Riempie Draw Stone.*—A flat slab of stone is at times found with a smoothed surface indenting one side, which concave edge is thoroughly rounded and polished. This is due to its use by Bantu people as a riempie or hide-thong drawer, the stone being placed over the thong, kept in place on the ground by one foot, and the thong drawn out over the concave edge by hand.

*Hone Stones.*—The Bantu hone stone is characteristic, especially that associated with the stone-building culture, which has a long, worn groove, parallel-sided, varying in length from six inches to over a foot, suggesting that long metal blades of flat blade (as opposed to ogee) technique were used. These are characteristically Bantu.

*Bead Polishing Stones and Awl Sharpeners.*—In the first, some preparation of the U-shaped groove is essential, and thereafter its extension becomes incidental to the process. In the second, the stone is prepared, but not the V-shaped groove, which usually is wholly incidental to the process of awl sharpening.

*Palettes.*—There are two types of palettes: A, oval or other outline, with convex surfaces, which probably were not palettes but body rubbers; B, the true palette, round or oval, with one or both sides slightly concave from use as true palletes or paint mixers, which may be made from shale, sandstone, or even granitic exfoliations.

A. The Coldstream Cave (4) produced a triangular palette, also the Matjies River Cave. The Oliphants River Valley, Cape Colony, and Beaufort West, and Leitjesbosch, C.P. (S.A.M.), also, which Péringuey called "besmearing palettes" (4, p. 161). They are distinctly scraped to shape, as are those of late Smithfield Caves in the Tsomo Valley in the Transkei (P. W. L.) and in the Wilton specimens of the Grahamstown area (Hewitt 15).

A long, narrow specimen was found at Bowker's Pass in the Western Transvaal, which though convex on the one side is

slightly concave on the other, and possesses a ridge near the narrow end which Abbé Breuil (14) considers was designed for holding it.

B. This type occurs on the Smithfield B-type site Avalon (P. W. L.), and possibly the Port Alfred midden specimens (7, p. 257) associated with Wilton implements also fall into this class. This type is associated with, and may possibly shade into, the thicker, heavier, stone paint pot of the Bushman. Little attention appears to have been given to their typology or distribution.

The best series is that recorded by Hewitt (15) from caves in the Albany District, all being oval in shape, and in dimensions, 20·4 cm., 7·6 cm. × 0·6 cm. Edges have been rubbed down, and vary from sharp to blunt, and in two specimens are notched. All are referred by their recorder to Wilton.

*Arm Rings.*—Polished stone in form of bracelets, which is based on an extension of the kwe boring technique to which is added polishing, are widespread and ascribed by Lowe to Smithfield. They have been found at Koffiefontein in the Free State and by the writer in the later shell-mound industries at East London (16), and also at Middledrift, and occur in the Smithfield B of the Free State. They are recorded from Wilton sites (15).

*Beads and Pendants.*—In the earlier cultures are rare. In the early Bantu deposits of the stone-building culture, especially in the Western Transvaal, they are fairly common, consisting of soft stone cut to shape by metal blades and scraped to a finish.

*Stone Borers or Reamers.*—Smooth, cylindrical, and pointed stones, such as those illustrated by Péringuey (4), were said by him to be smoothers for the holes in digging stones, though why they should be so smooth, or why the hole in a digging stone should need to be smoothed, is not explained. All the kwe reaming stones that the writer has handled in his area are ground down to a roughly conical, but not pointed, shape by rotary motion. They are not polished, *i.e.* the grinding on them as on quern or millstones is incidental to the work performed with the tool, and gradually deteriorates it. Further, there is obvious confusion between true kwe borers or reamers, which are rough, and highly finished, pointed, cone-shaped stones of totally different origin which are considered separately below. The former occur in Smithfield A and B (7) and have been found in an earlier deposit with M.S.A. affinities in the Transkei (17). These Transkeian reamers are made of naturally pointed stones, usually three-cornered on section, often thermal flakes off hard rocks, and rarely prepared. In the Free State Smithfield culture they appear to have

received some preparation. They develop a typical band of wear, cylindrical on section.

*Digging Stones* (perforated and of various shape).—Certain digging stones have been carefully shaped by pecking and battering before being ground smooth. Polishing occurs not only among those made of softer stone such as agalmatolite. It is stated (7, p. 162) that they occur in Smithfield A, B, and C. The best made being associated with B. Smithfield industries occur in the Cape only in the north and east, but kwes are found occasionally in definite association with Wilton, and occur prolifically in Namaqualand where no Smithfield implement has ever been found. Goodwin, however (7), did not include bored stones among the normal associations of Wilton. Bored digging stones are found occasionally in Southern Rhodesia, though not frequently associated with Wilton. They are, in fact, ubiquitous in Africa, but this has not prevented certain other bored artefacts, namely pipes, being classed as digging stones, or children's digging stones from time to time.

*Pointed Polished Cones of Stone.*—These are at times described as pestles, though examination of a series shows no battering or wear that would be expected from such use. They are also claimed to be mandrels on which metal rings and bracelets were made. Again, none shows the marks of such usage, nor are the sizes suitable except for children. There is still a degree of obscurity concerning their origin and use. They vary in length from 5 cm. to over 18 cm., and have a basal diameter of about 6 cm. Their distribution appears to be limited to the stone-building culture area.

It is intended to discuss them in detail elsewhere, and the subject is introduced here only on grounds of technique and distribution.

*Double-pointed Polished Stone Artefacts* (egg-shaped).—These also do not appear to be designed as implements. Of the two in the writer's collection, one was found outside a dilapidated Bushman shelter on the Tsomo River, Transkei. It is 16·6 cm. long between points and its body is slightly flattened, being 6 cm. in the narrower diameter and 7·2 cm. in the wider. The stone is hard and heavy and has been carefully polished over its whole surface.

The other is a similarly shaped and finished stone of slightly smaller dimensions, 12·4 cm. long and 5·6 cm. diameter. It was purchased in Johannesburg and was stated to come from Swaziland. It has been turned into a kirrie by shrinking a band of leather round its middle part, which is fixed also to a stick covered with leather. As far as may be ascertained no Swazi or other Bantu ever polished a stone of this description. It is believed to be Bushman in origin and therefore companionable with the first described. Natives to whom it has been shown ascribe it to Bushmen.

A similar artefact is described by Péringuey (4) and discussed under the heading "brayers, mullers, and mortars." It was discovered while making a railway line near Cape Town and is "as smooth as if it had been polished." Another (4) from the southern portion of the Kalahari "shows no mark like that which a hammer would leave." These stones probably fall within the category of symbols and may have some relationship with the pointed cone.

*Cylindrical Stones with Rounded Ends.*—A specimen of which the history is unknown was in the S.A.M. before Péringuey became Director. He suspected that it came from Mossel Bay. It is cylindrical with rounded ends, ground or pecked to shape, unpolished, and ornamented with a broad band of pecked marks. Péringuey mentioned (4, p. 119) that he knew of others. These probably included a specimen from Klein Brak River, another 49 cm. long (Alb.) earlier figured by Schonland (18).

Péringuey considered that the double-pointed Kalahari specimen was used as a beacon by the (pastoral) Hottentots or perhaps by the (hunting) Bushmen to denote the limits of their grazing grounds; a notion for which there is no supporting evidence. They may be boundary stones, and on the other hand may be an offshoot of the preceding section. Stones of this type are rare, though of somewhat wide distribution. In no recorded instance has one been found in association that would suggest an age greater than that of the Late Stone Age, and cultural association is rare.

*The Ground-edge Implements.*—Apart from the arm ring, in which the edge is incidental, these may be roughly classified into

(*a*) axe or adze-like implements;

(*b*) knife-like blades;

(*c*) the assegai type blade;

and they will be considered in this order.

A number of partly ground-edged implements of an axe or chisel form have been found in the Cape Province. They are usually formed on natural stones. A "ground stone axe" of local stone was found (19) in a rock shelter at Witsands, near Kommetje, C.P., associated with rough choppers, cores, bone spatulae, potsherds, pot lugs, a "well-recognised culture, that of kitchen midden," which probably was late Wilton. This artefact has an edge of $2\frac{1}{4}$ in., is approximately rectangular, and is ground on part of the surface only. It is claimed that it was undoubtedly hafted.

Hewitt described (15; and 4, fig. 26) two polished stone artefacts from the Albany area. The first was previously described by Schonland (18) and shows abrasion marks "clearly indicating" hafting to its recorder. It is made of dark greenish quartzite, 8 cm. long, 6 cm. at its widest, and 4·8 cm. at the point where it narrows to the butt, which is shaped by

pounding. Between this and the ground edge the surface is striated, the natural contour of the stone or pebble surviving to a great extent. The second was found in a rock crevice at Paradise Kloof, Grahamstown (fig. 1). It is ground on both surfaces, has a cutting edge of 2·5 cm, and is tanged. It is flat and thin, and is likened by Hewitt to the polished palettes. The Abbé Breuil suggests (8, quoting Breuil) that this specimen is not a neolithic axe in any sense of the word. It is of ochreous material and would "stand very little use as an axe or cutting implement."

The Peddie axe (S.A.M. 3449; and ref. 6) (fig. 2) was found seven miles from the coast. It is formed out of a water-worn quartzitic sandstone pebble, and is in shape roughly a tapering cylinder, 12·7 cm. long, and with a ground-cutting edge of 6·4 cm.

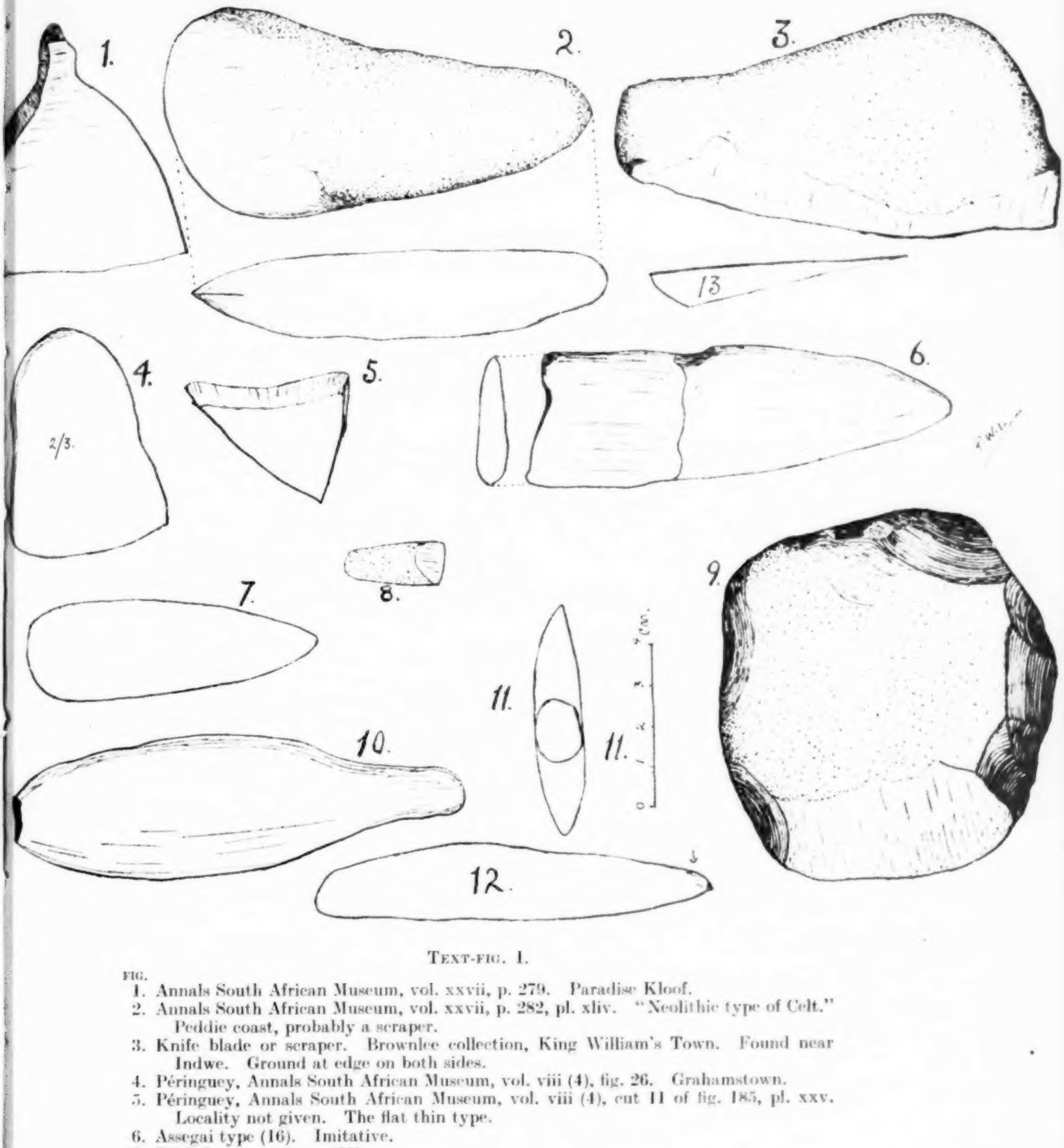
The Piquetberg specimen in the Stellenbosch University Museum is oval, of argillaceous sandstone, pecked to shape, and one end sharpened by grinding with a lateral motion.

A perforated specimen from Koster is recorded (7, p. 281). As this comes from well within the stone-building culture area, it may fall outside any possible "neolithic" period.

An axe-shaped artefact was found recently in a shell mound on the Buffalo River at East London (E.L.M.) (Plate II, fig. 2) and is very similar to the Peddie specimen. The mound contained a late culture, with pottery, and an eighteenth-century large opaque white glass bead. The artefact is formed on a water-worn pebble 10·3 cm. long, 3·3 to 3·6 cm. in diameter. The greatest depth of ground edge is 4·0 cm., and breadth is 3·6 cm. The pebble does not appear to be artificially shaped.

The Albany Museum possesses an unrecorded specimen (Plate II, fig. 1) from Kleinpoort in that district, which the writer is enabled to describe through the courtesy of Dr. Hewitt and the Board of Trustees of the Albany Museum. It is of doubtful association, and is definitely a surface find. It is made of a slab of Dwyka shale, shaped by rough flaking, battering, or pecking to a rectangle of 121 × 51 mm. and of a maximum thickness of 25 mm.' The edge is ground on both sides, forming a double bevel, and is somewhat curved, but not regularly so, over a breadth of 38 mm. Dr. Hewitt does not consider that it is Wilton, and is of opinion that it belongs to the same industry as that of the pecked and battered "rolling pins" and "clubs." In this opinion the writer concurs.

Goodwin (8) was the first recorder of ground-edge artefacts in the Transvaal and described two. The first, 77 × 44 × 43 mm., which is perforated for hafting and was found between Potchefstroom and Ventersdorp, was associated with a digging stone. This isolated perforated specimen was claimed to imply "the presence of a true neolithic influence in close association with a known culture" and a knowledge of European




TEXT-FIG. 1.

FIG.
1. Annals South African Museum, vol. xxvii, p. 279. Paradise Kloof.
2. Annals South African Museum, vol. xxvii, p. 282, pl. xliv. "Neolithic type of Celt." Peddie coast, probably a scraper.
3. Knife blade or scraper. Brownlee collection, King William's Town. Found near Indwe. Ground at edge on both sides.
4. Péringuey, Annals South African Museum, vol. viii (4), fig. 26. Grahamstown.
5. Péringuey, Annals South African Museum, vol. viii (4), cut 11 of fig. 185, pl. xxv. Locality not given. The flat thin type.
6. Assegai type (16). Imitative.
7. Penhalonga specimen (10).
8. Salisbury commonage specimen (10).
9. Mtoko Cave (11). The hand-axe type, shaped, thin, one edge ground.
10. Assegai type (12). Imitative type.
11. Assegai type (12). View from haft. Imitative.
12. Blade or knife or scraper type. Ezolo, Transkei (P. W. L.). Ground one edge only.
13. Cement-floor polisher, section of. The size is 12 cm. long, breadth varies from 5 cm. to 7 cm. The "edge" is sharp only in portion of its circumference, the remainder being rounded as is the back, into which it grades.

or native axes of metal. It is the only wholly polished axe-like implement that has been found in South Africa. The second specimen came from the same area, is roughly circular, 77 × 81 × 28 mm., and has a polished surface that was first prepared by pecking.

Goodwin also described certain Rhodesian specimens, four in number (8):

| | | | | |
|---|---|---|---|---|
| 1. | 100 mm. × | 67 mm. × | 41 mm. thick— | quartzitic sandstone |
| 2. | 104 | 70 | 34 | ,, ,, |
| 3. | 82 | 58 | 25 | greenstone |
| 4. | 80 | 78 | 28 | ,, |

No. 1 showed signs that the surface was pitted or pecked to ease grinding. The stone was chipped to shape it or reduce its size in each specimen. No associations are recorded, and it appears that all were surface or near surface finds. These four specimens do not appear to have been included by Stapleton in his notes on certain ground artefacts (20) found in Southern Rhodesia; mostly they are flat, axe-shaped, except four which are cylindrical. One was found on the surface of a Wilton cave, another from a Wilton cave at Gokomere. They are formed on dolerite, aplite, granulite, epidorite, and granite, and vary in size from 69 × 30 × 25 mm. to 104 × 86 × 36 mm. for the flat, and for the cylindrical 69 × 30 mm. to 200 × 66 mm.

The Revue River, Penhalonga, specimen (fig. 7) is the fourth so far recorded axe-like specimen in South Africa of which the whole surface is ground, and it is because of this more celt-like than any other South African specimen. Father Stapleton claims it as an undeniably neolithic celt. Another instance, also Rhodesian, is a slender celt-like artefact of polished "flint" (and if flint, probably introduced) found on the Bulawayo commonage many years ago. Stapleton's illustration 6, a broken fragment, cannot be definitely ascribed to the same class, but more reasonably can be ascribed to the class of polished phallic stones. Two Rhodesian specimens of differing technique are illustrated in figs. 8 and 9.

Neville Jones arrived first at an axe-shaped specimen, seen by both of us simultaneously on the surface of cave débris at Echo, near Salisbury. This specimen is now in the Bulawayo Museum.

The great majority of the Rhodesian specimens are either surface finds or from hill wash.

North of the Zambesi, polished or ground-stone artefacts are much more common. This type is, then, of very wide distribution, increasing in incidence northwards.

*Knife-like Blades.*—Stone slabs with one edge ground are uncommon. One is illustrated by Péringuey and here reproduced in fig. 5 (4, fig. 185, plate xxv, and p. 166). It was found in a rock shelter between Wepener

and De Wetsdorp, O.F.S., and is made of a piece of flat stone of which the crescentic upper part has been ground to a sharp-cutting edge. Its associations are Late Stone Age, with important fragments of pottery of a late type, the Tarka-Queenstown type belonging to the period of Bantu immigration into the area. Other massive fragments found in association suggest that a proportion of the potsherds are of direct Bantu origin.

The writer has a knife-like blade of soft stone from the Transkei (fig. 12), and a second from a shell mound at Umhloti, Natal. Dr. Brownlee of King William's Town has another from cave débris near Indwe (fig. 3). In both instances there is no record of direct association and they are probably all surface finds. Hewitt found a slab of shale with a ground edge at Rufane's River in the shell mounds there, and believes that such artefacts occur only where suitable slabs of shale are easily obtained (15). A similar blade, formed of a thin slab of sandstone and ground to an edge, was found on the Avalon Smithfield B-type station (7, p. 166). From Knysna came a small sandstone specimen, ground on each side to produce an edge (S.A.M.). Hesse's specimens from Britstown have already been mentioned. Again, in no instance is there any indication of great age. The distribution of the type appears to be limited to the O.F.S and South-East Cape.

*The Assegai Type.*—A class of polished implement that appears to be quite distinct from the foregoing is a long blade, carefully polished to a degree of flatness and double-edged. These have been described so far from two districts only—Regina in the Western Transvaal (21), and from a Natal coastal site at Karridene (22). The latter are unfortunately broken. They are described by their finder as lance heads. The larger of the two found is reproduced in fig. 6. A third such was found on a Smithfield site near Durban North (22). No comment is made by the finder. The former, Transvaal specimens, are described by their discoverer as neolithic stone implements, polished neolithic spearheads. They were found with two polished stone rings at a distance of twelve feet from the surface while well-sinking some years ago. The proximal ends are shaped (figs. 10 and 11) and suggest hafting, and it is considered that they could have been made as daggers (21). The stone of which they are made is soft, a "mixture of soapstone and quartzite." The polishing has been carried out in three directions—longitudinally, transversely, and obliquely. The discoverer claims that these form one of the most complete evidences of true neolithic art in stone which the country has yet presented, and that such evidences are continually being increased, and classes them with ground-stone axes and polished conical stones.

CLASSIFICATION.

*South African ground or polished artefacts* produced incidentally to a technique or use.

I. Bushman grinding mill, oval, long, and narrow.

II. Bushman muller or grinder, natural stone or pebble with cortex, ground down gradually and frequently both inland and on coast with a pecked hole on grinding surface to assist grinding.

III. Bantu mill or quern stones, large, heavy, great area hollowed. Bantu snuff mills, small and much hollowed.

IV. Bantu mullers or upper stones:

V. *Modern:* Bantu cement-floor polishers.

VI. *Ancient:* "Penny bun" *tsele* stones, double facets on one or both faces.

VII. Hone stones: Bantu, for sharpening metal blades.

VIII. Bead polishing stones, Late Stone Age, and occurring also in sealed deposit with earlier phases with strong aurignacian or early capsian affinities. Groove a section of a circle. They occur in the early capsian of North Africa (11). May belong to either this or the following class.

IX. Bone awl or arrow sharpener. Late Stone Age. Groove V-shaped.

*South African ground or polished artefacts* produced by intent for a specific purpose:

A, ornaments; B, objects of ritual or other significance; C, implements other than ground edged; D, ground-edged implements.

A. Ornaments.

I. Stone beads and pendants. Modern Bantu, and ancient stone-building culture Bantu.

II. Stone arm rings of Late Stone Age (Bushman?) origin, in which boring, grinding, and polishing are combined to form a distinctive article. The only wholly polished and highly finished type of definite non-Bantu origin. More common in Smithfield, less so in Cape Wilton, absent from Rhodesian Wilton. They are found also in Sahara sites.

III. Stone pendants of Late Stone Age origin. (These are being described in a forthcoming paper on beads.)

IV. Bead polishing stones.

B. Objects of ritual or other significance:

I. "Boundary" stones, Bushman and Hottentot. The double-ended tipcat shaped and polished; and the more cylindrical, pecked,

probably form two different classes. The former is limited to east and south of Cape Colony in the hunting and pastoral culture areas.

II. Phallic stones occurring only within areas affected by the agricultural stone-building culture. They are polished cones of circular section, and rarely show signs of use. Distribution appears to be outside that of B(I).

C. Implements other than ground edge.

I. Paint or true palettes, with concave surface; occurring in caves of Wilton and Smithfield industries, and on open sites of the latter.

II. Strigils, or body-paint applicators, convex surfaces. Found in similar association.

D. Ground-edged implements.

I. Axe-shaped scrapers, the most widely distributed of all types within this section from the Cape to Rhodesia, made of natural pebbles, commonly battered or chipped to shape in the north, rarely so in the south. It should be particularly noted that in the south, where highly polished arm rings are more common, highly finished axe-shaped-edged implements do not occur.

II. Adze-shaped scrapers, which may be shell detachers, or merely atypical forms of D(I). They also are widely distributed from the Eastern Cape to Rhodesia, and there does not appear to be any real reason for separating these two types. The East London specimen is Late Stone Age and associated with pottery.

III. The dagger or lance heads types of which only five have been recorded to date. Found only within a limited area—Regina, Transvaal, and the Northern Natal coast. The Regina specimens were found associated with polished stone rings. The method of finish of this group is of interest, it is in three directions, longitudinally, and from either side. They are not fully polished.

IV. Slab-like knife blades. Single-ground edge. The stone is usually unsuitable for a cutting edge, is single bevel, and they are probably merely atypical forms of D(I).

## Discussion and Conclusions.

So many of these widely scattered, somewhat rare, artefacts of very varied type have been hailed by their describers as undoubted neolithic, or as most complete evidence for the presence of such a phase, that one

hesitates to accept any of their arguments for the existence of a widespread neolithic culture on the basis of such finds. It appears that because there is an undoubted neolithic culture in North Africa, South African recorders pounce upon any superficial similarity in a ground or polished artefact as a sure indication of the presence of that phase. Goodwin stated (11) that "It is an extremely difficult thing either to define or to confine the term 'neolithic.' The polishing of stone is not in itself a sufficient criterion." Father Stapleton, in a communication to the writer, stated he was not prepared to ascribe stones with polished edges to Bantu, nor to call them neolithic unless all ground implements are included in the term.

In the foregoing description of the morphology of certain artefacts, a distinction has been drawn where possible between the terms "ground" and "polished." Grinding is undoubtedly the first stage towards polishing, and artificial or natural grinding must precede polishing. In the preparation of a stone surface, grinding is distinct from pecking. A pecking technique is used by Bushmen and Late Stone Age man for the preparation of stone surfaces, and with them grinding was incidental to a process. Pecking was utilised as a technical process to produce an effect, namely roughing of a grinding surface, to a small extent by Bushmen, but generally by the Bantu. Grinding is incidental to certain processes in almost all ages and cultures. Grinding as a technical method to produce an implement is not. A quern stone found in M.S.A. association (P. W. L) shows natural lines formed by its laminations, crossed by incised lines to roughen the surface. The presence of such a stone in such association militates against Burkitt's arguments. Also, an edge, whether ground or polished, though intended for dividing substance, is not of necessity, because of its oblong shape, an axe with symmetrical bevel to be used by a blow, or even an adze with unilateral bevel; nor is an edge of necessity a cutting knife or a razor, whether it have a single or double bevel, but is equally well utilisable for scraping, when the whole length of the edge is used, in the manner of a cabinet scraper.

Axes and adzes necessitate hafting, and so do assegai blades and certain knife blades. Evidence of prehistoric hafting is exceedingly scarce in South Africa. Hewitt has, the writer believes, evidence of scraper-hafting in Wilton. That recorder also published an account of a hafted stone.

That grinding marks and striae are evidence of hafting is difficult to believe. There appears to be nothing whatever to suggest a firm usable hafting of the Witsands "axe," and the "clear indication" of hafting in Schonland's specimen also is extremely doubtful. Breuil's remark on the ochreous material of Hewitt's specimen is a final disposal of the axe

theory so far as that specimen is concerned (the soft nature of certain ground blades equally well precludes their use as knives). There is, further, no evidence whatever that either Hottentot or Bushman ever used an axe or axe-like implement, and no specimen has so far been recorded from South-West Africa.

Father Stapleton draws attention to a possible production of such ground stones as the result of over-use of the *tsele* or upper millstone by the Bantu continually grinding cereals. His items 3 and 10 (20) he suggests are the result of such over-use, until the two grinding surfaces met and produced an edge, when it would be thrown away. This is faintly possible, but not probable. Single-faced as well as double-faced *tsele* stones were used. Both show the double facet on the worn face produced by push-and-draw grinding. Of the thousands seen by the writer not one was thin, and further, any such stone thinned even to double the thickness of an axe-like artefact would give no grip for grinding. These thinned stones have two single facet faces, not parallel, and so liable to give an edge where the two faces meet. These stones are cement-floor polishers used only by the Bantu, historic and prehistoric, and such the writer has purchased from the Bechuana in Bechuanaland, and has also recovered from the building-culture ruins of Southern Rhodesia in which relics of cement floors still survived. The ground-edge artefact, the *tsele* stone, and the floor polisher have nothing whatever in common except that certain surfaces are ground ; each is easily distinguishable from the other, though the tyro might mistake a floor polisher for an edged implement if he did not examine it carefully.

The differential distribution of these types and sub-types is clear and generally signifies a late restricted culture, with the exception of D(1), the axe-shaped artefacts, which are widely distributed. Many of the specimens are similar in appearance, and in technique of pebble preparation by chipping, to the shell detachers found in shell middens. The ground edge, however, puts this implement into a class of its own. No specimen shows indisputable evidence of having been hafted, there is no archaeological or ethnological evidence of any chopped implements of wood or bone, or of axe-damaged skulls. There is, in fact, no real evidence to support the existence of stone axes in South Africa, while there is the evidence of certain soft-stoned specimens that such was not their use or intent. The four completely polished specimens and the single perforated specimen, on the use of which without handling it is not intended to dogmatise, are all northerly in distribution, that is from the Vaal River to Southern Rhodesia, a part of the land reached by culture migration that never touched the Free State or the Cape. Certain forms of axe-like polished implements are found all over North Africa, the Cameroons, and

Ashanti (23), and they are most highly developed in the Welle Basin of the Belgian Congo, where they prove to be not cutting but scraping implements. The "neolithic celts" of Nigeria (24) vary considerably in material, size (19 cm. down to 11·5 cm. in length), outline, and section. They are found with tree-trunks in a wash, which tells against high antiquity. All are rough towards the butt end, and the edge only is polished or ground. If a Tumbian origin is claimed for South African ground-edged artefacts, it is reasonable to claim also Tumbian use. If this source of influence is accepted as reasonable, and it appears to meet the time-entity requirement, then the theory of North African Capsian origin, or Egyptian neolithic origin, as a direct source must be dropped. Palettes, for example, occur in Egyptian neolithic. If the "South African Neolithic" is a southern migration of this culture, it is necessary to explain why such a useful implement as the axe, surely still more useful in the heavily wooded south, fell out of the industry. Actually, in South Africa, the palette is an item of upper palaeolithic assemblages, and has never so far been associated with tanged or barbed arrow heads. They show that same knowledge of grinding, shaping, and polishing which was possessed by the makers of arm rings, neither of which implements was ever used as an edged tool, and both of which are associated with pottery only in their latest stages when potting had been introduced from the north by the Hottentot and Bantu, and also quite unassociated with agriculture. North African definitions of the term "neolithic" can, therefore, not be applied to South African conditions.

Classes or types A and C show that the stone workers of the South African Late Stone Age possessed a stone-polishing technique probably based on observation of the results obtained unintentionally on mill stones and grinders, which was of ancient lineage. It was, however, put to use for ornamental purposes only. Type B(I), of tipcat shape, is so rare and so limited in distribution that it may well be an application of ancient cultural technique for ritual purposes, while still being equally well the result of contact with the makers of B(II), the cone-shaped phallic stones. Their distribution does not appear to coincide.

There is evidence that suggests a separate origin for certain types. The occurrence in the Matjes River shelter excavated by Professor Dreyer of Bloemfontein, of bone or ivory ground-edged tools (Bl.M. H. 364T, H. 3667, H. 3668), suggests strongly that the adze-shaped-edged stone tool of the East London and other middens is of similar origin and use, and that the art of grinding an edge was first applied to the more easily worked bone. One of these bone tools (Bl.M. H. 3667) is a rib worked to a chisel edge or single bevel, 37 cm. long with an edge 3·5 cm. broad. Others are of thick bone, with a double-bevelled edge. These might quite well have

been used as axes, but there is no sign of hafting or preparation for hafting, or of use with blows. They could be used as shell detachers, but again show no abrasions as would be expected after such use. Being found in a mass of shells suggests that they were shell emptiers, *i.e.* a table utensil of scoop type which has a parallel in the Azilian shell middens of Scotland. In this case the application of the technique and intent may well be locally and independently developed.

There is, however, another distinct class to be dealt with and explained, D(III), the dagger or lance-head types. It is noticeable in the Bushman paintings of the Transkeian area, where the painter-hunter came into contact with the agricultural metal-working Bantu, that the assegai blade represented in the hands of Bantu is caricatured, being enlarged and painted in a dense heavy white. They are shown also in the hands of Bushmen. The stone blades of this class come from an area in which the Bushman came still earlier into contact with the Bantu, and his imagination was surely equally struck by the glinting white blade, which he could reproduce only in stone through the application of his ready knowledge of stone grinding. It is, therefore, proposed to class these implements as imitative. If this is accepted, then it follows that the implement was not evolved by its maker, and cannot be classed as truly neolithic. That the introduction of worked metal into Southern Africa had a bearing upon the Stone Age is suggested also by the finding of an iron chisel in the Snake Shelter at Cala (25) associated with mural paintings and stone artefacts.

There is, then, the probability of local evolution for types A(II), C(I) and (II), and D(II); of introduction of a technique from the north for Type D(I), and of imitativeness for D(III). It is concluded, therefore, that it is not wise to use the term "South African Neolithic" as a term including all these types, and that descriptions of such artefacts should be more thorough. If the association of pottery is required to fulfil the definition, then in South Africa polishing and grinding long antedates its introduction, and some other term must be found. Further, in the European neolithic the axe-shaped artefact is an axe, in South Africa it is not.

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Alb.—Albany Museum, Grahamstown.
S.A.M.—South African Museum, Cape Town.
P.W.L.—the writer's collection.
Bl.M.—Bloemfontein Museum.
E.L.M.—East London Museum.

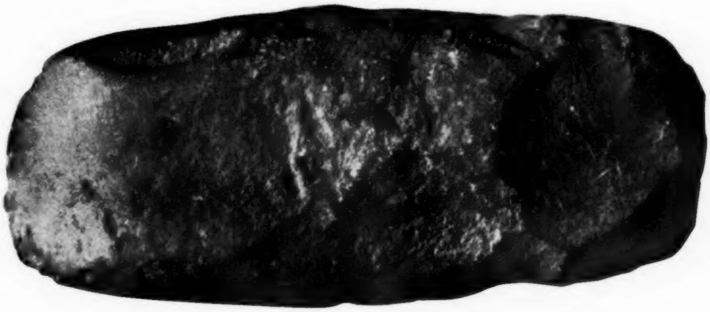


Fig. 1.

Fig. 2.

P. W. Laidler. Neill & Co., Ltd.

# A SURVIVING FISH OF THE ORDER ACTINISTIA.

By J. L. B. Smith.

(With Plates III–VII.)

## Preliminary Announcement to the Society.

(Read March 15, 1939.)

The various reports and one or two popular articles which have appeared in the daily papers will already have informed members of the Society that an important scientific discovery has recently been made near East London. Since it is my privilege to announce the discovery to the scientific world, it has seemed advisable to issue this preliminary announcement to the Society, to give my opinion of the identity of the specimen, and some authentic details of its structure, since the full description and sufficient figures will take a considerable time to prepare.

The specimen is a Crossopterygian fish of a type believed to have become extinct during the Cretaceous period. Those fishes had for a relatively long period of time been very widely distributed, and palaeontological records indicate that they occurred in vast numbers. From the close of the Mesozoic period to the present day, no trace of living or fossilised Actinistian or Rhipidistian fishes has been found, and all species had been supposed to have become extinct. The fish recently obtained shows that in some remarkable manner one species at least of the order Actinistia has survived, and the discovery opens up all kinds of interesting possibilities.

This fish was taken by a trawler at a depth of about 40 fathoms off the mouth of the Chalumna River, west of East London. It was alive when caught, so vigorous as even to snap viciously at the hand of the captain, and showed signs of life for almost three hours after capture. Shortly after the specimen had died, it was handed over to Miss Courtenay-Latimer, Curator of the East London Museum. Since I generally classify fishes for the Museums in the Eastern Cape area, Miss Latimer wrote to me, enclosing a sketch and brief particulars of the specimen. Owing to some seasonal disorganisation of the postal services, the letter did not reach me at Knysna, some 400 miles away, until 10 days later. Since it was

obvious from the sketch and notes enclosed that the fish was of a type believed to have been long extinct, immediate telephonic contact was established with the East London Museum. This revealed that, owing to lack of suitable preserving equipment and facilities at that Institution, the putrefied carcass had been disposed of beyond the faintest hope of redemption, and the fish had been mounted by the local taxidermist.

In order to stress the extraordinary nature of the discovery, I may inform the Society that even with further information and details supplied by Miss Latimer in reply to my questions, it took a considerable time before I could bring myself to believe what the information apparently represented. When I eventually wrote to Dr. Barnard of the South African Museum to inform him of the find, and to acquaint him with my opinion, it took him also some time to realise that my communication was in earnest. It has indeed come as a shock to the ichthyological world.

Since the fish was unquestionably alive when caught, there is a possibility that the tragic loss of the body may be remedied by the capture of another specimen. It is difficult to account for there having been no previously recorded capture of a specimen of this species. It is possible that it has lived in some region where man seldom penetrates, either at great depths or in some unfrequented stretch of ocean, and that the present specimen is a stray. On the other hand, it may normally live a sluggish life among rocky ledges where trawlers cannot operate and at depths greater than those at which line-fishing is practicable. It appears only remotely possible that the species is not marine. Reports have now been received which indicate that specimens have previously appeared. A reliable citizen-angler of East London has stated that he had some five years previously come across exactly such a fish, only considerably larger, partly decomposed, cast up by the waves on the shore some miles east of East London. He described the specimen in such terms as to render it very likely that he was not mistaken, and stated that when he returned with assistance to fetch the monster, it had disappeared with a risen tide. Also, though probably less reliable than the above, is a statement emanating from some member of the crew of a fishing vessel, that one of them had seen no less than six such fishes taken in one haul near Durban. All had been discarded as unknown vermin.

It may be recorded that both Miss Latimer and the taxidermist had fortunately paid very close attention to details of the carcass during and after skinning. Exhaustive questioning has left me with at least some fairly definite information about the missing parts. Fortunately also, the terminal portion of the vertebral column and part of the pectoral girdle remain. The skull is apparently intact. The mounted specimen is 1500 mm. in length (the fresh specimen was 1400 mm. in length, *fide* Miss

Latimer), and weighed 127 lb. when fresh. The colour was a bright metallic blue, which has faded to brown with preservation. The alimentary canal was entirely empty.

So close is the specimen to the Mesozoic Coelacanthidae (order ACTINISTIA) that it is at present assigned to that family. The gephyrocercal caudal with protruding axial supplement, the normal first dorsal (posterior membrane joined to body), the obtuse lobation of the remaining fins, the ganoin tubercle and/or spine ornamentation on the scales (Pl. V) and on part of the dermal bones of the head, the nature and arrangement of the dentigerous bones of the mouth, absence of maxillae, and the form of the dermal armour of the head, are all typically Coelacanthid. The teeth are mostly conical, the dentition consisting almost entirely of dermal plates which are very obviously merely metamorphosed scales. A lateral line, complete to the end of the supplementary caudal, is present, the lateral line tubes bifurcating posteriorly (Pl. V). The present specimen has spiracles, small but distinct, of such a nature that it is unlikely that they would show in fossilised remains, although it is now easy to place the spiracles in reconstructions since they lie at the lateral ends of the fronto-parietal joint. The dermal armour of the head actually corresponds more closely with that of earlier rather than that of later Coelacanthids. The fins appear to be more pedunculated as compared with those in many of the extinct forms (Pl. VII). There are two small heavily ornamented bones at the anterior lower corner of the opercular plate, which appear to correspond with the inter- and sub-opercula of Teleosts. There is also a similar post-spiracular ossicle. (These three bones may be merely superficial ossifications of the opercular membrane.) Parafrontals are present beneath the skin, the fronto-rostral bones being somewhat stellolaminate, and there is an ossified segmented free "tongue" (dental plate) covered with tubercles resembling those on the scales. The gular plates are large and heavy (Pl. IV).

The Coelacanthid genera appear to be founded on characters which in modern fishes would be regarded as slender. The present species cannot be assigned to any known genus in that family, having indeed features characteristic of several, so as to indicate that a revision of the genera will be necessary. It is, however, beyond dispute that the species is a Coelacanthid, feature by feature the coincidence being most striking. It may occasion surprise that a Mesozoic form could change so little over so relatively vast a period of time as from then till now. It has, however, been noted that certain Coelacanthid fishes underwent little apparent change from the Devonian to the Cretaceous, a considerably longer period.

This specimen shows in the main how close to the truth have been the reconstructions by palaeontologists. Some modifications will be necessary,

chiefly the forms of the reconstructed fins. It has not been realised that the problem of the homologies of the bones of the head has probably been rendered more difficult by the absence of uniform bilateral symmetry. In my specimen on the left side the squamosal is single, whereas on the right it is divided horizontally into two separate bones. Also the "sub-opercle" is missing on the left side.

It was related to me that the flesh of the specimen was of a faint greenish hue, and plastic, almost like soft putty, even when fresh. It was remarked that there was no sign of red blood anywhere about the fish, not even about the gills or vertebral column. The gill-filaments were apparently normal, and of a reddish hue. The gill-arches are stated to have been spinescent, with a few larger recurved hook-like spines on the upper surfaces apparently set in coalesced bases of surrounding smaller denticles, much as the teeth in the jaws. The skeleton was cartilaginous and soft, the vertebral column apparently acentrous, with the notochord presumably persistent. The whole fish was abnormally oily, the skin alone exuding a relatively great amount.

The specimen almost certainly represents a new species, and in so far as I can determine, a new genus also. I have already designated this specimen *Latimeria chalumnae*,* falling in the family Coelacanthidae, and diagnosed in outline by the description given in this paper.

A detailed study of the specimen is in progress, the results of which will be communicated to the Society as early as possible.

With the original of this paper was included only Pl. III. In response to numerous requests, Pls. IV–VII have been added. This is rather unusual in a preliminary paper, but is justified by the extraordinary interest the discovery has aroused.

I wish to express my gratitude to the Research Grant Board for financial assistance (Carnegie Fund), which has defrayed part of the costs of the investigation.

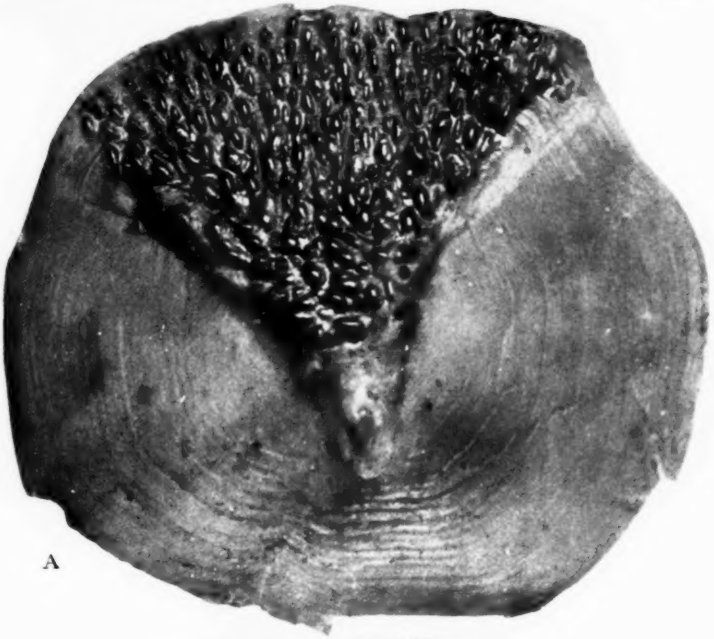
Albany Museum,
Grahamstown,
*March* 1939.

* Nature, London, Vol. 143, No. 3620, March 18, 1939, p. 455.

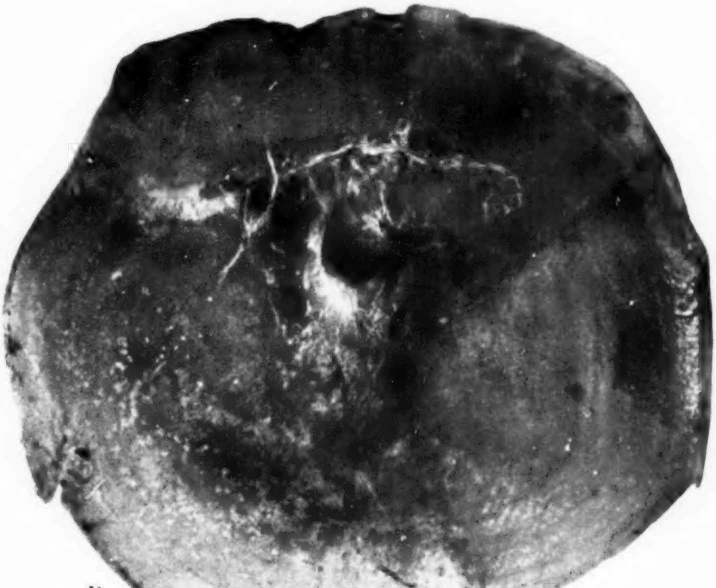
*Latimeria chalumnae* Smith. × ½.
The small arrow shows the position of the spiracle.

*Latimeria chalumnae* Smith. Ventral view. × 1/8.

*J. L. B. Smith.* *Neill & Co., Ltd.*



A



B

*Latimeria chalumnae* Smith. Ninth lateral line scale from left side. 3.

A. Upper surface showing bifurcated tube.
B. Lower surface showing perforation.

Posterior margin of scale above.

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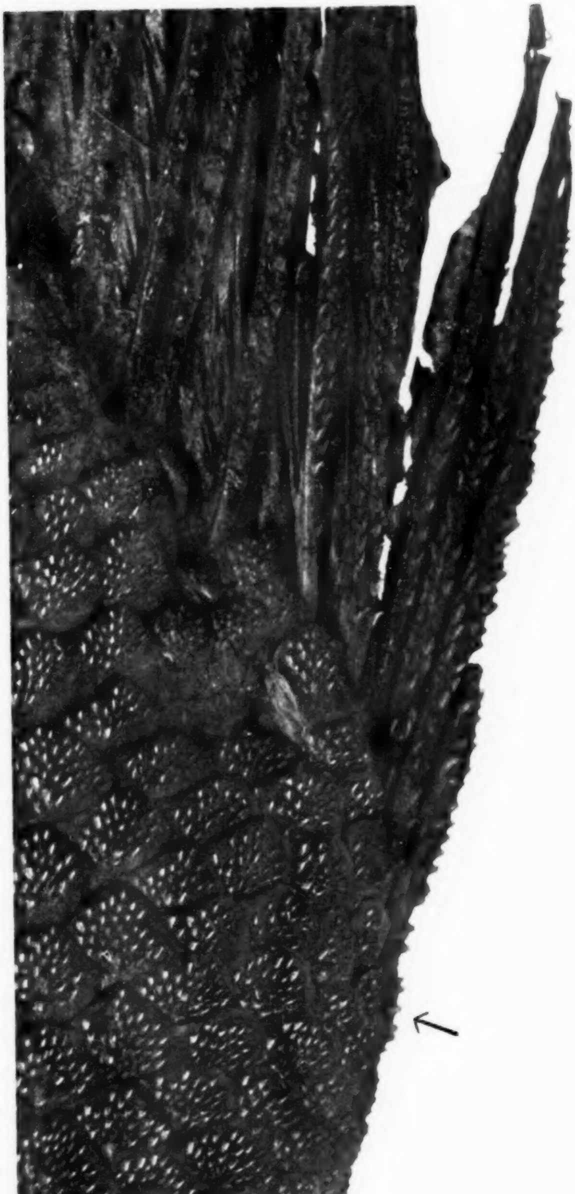

*Latimeria chalumnae* Smith. Anterior principal ventral caudal rays. × [illegible], showing some of caudal scaling.
The small arrow shows the first short ray.

J. L. B. Smith. Neill & Co., Ltd.

*Latimeria chalumnae* Smith. Second dorsal fin. × ½, showing some of the scaling. The small arrow shows the lateral line.

J. L. B. Smith. Neill & Co., Ltd.

# GROWTH CHANGES AND VARIATIONS IN WART HOG THIRD MOLARS AND THEIR PALAEONTOLOGICAL IMPORTANCE.

By J. C. Middleton Shaw,
Professor of Dentistry, University of the Witwatersrand, Johannesburg.

(With nine Text-figures.)

(Read August 17, 1938.)

CONTENTS.



## Introduction.

In the study of anatomy and palaeontology teeth have proved to be factors of great importance. Previous literature dealing with the teeth of modern and extinct wart hogs is incomplete, scattered and even contradictory and for these reasons the writer feels that the subject warrants a detailed investigation. The present report endeavours not only to add new information but to co-ordinate the facts already known. It is hoped that it clarifies a subject in which there is great confusion and provides a concise monograph for the use of future investigators.

Until a fairly recent date two species of the wart hog *Phacochoerus* were known. Lydekker (1894) and the majority of investigators of the last century described these species under the name *P. africanus* and *P. pallasi*, but in some instances the latter was called *P. aeliani*. Beddard (1923) and other modern authorities use the names *P. africanus* and *P. aethiopicus*, and it is generally agreed that the latter species is now extinct. Races of wart hog have also been described, but as in several instances the names given to these are the same as names used for species, it is frequently most difficult to determine whether the literature refers to races or species. For example, Lönnberg (1908), as a result of investigating the skulls in the British Museum, reported on five races of wart hog which he named *P. africanus*, *P. aeliani*, *P. massaicus*, *P. sundevallii*, and *P. delameri*. It will be seen, however, that the two former are names which are, or until recently have been, utilized to distinguish species of wart hog. Moreover, some later investigators have used a combination of names, the significance of which is not clear. For example, Van Hoepen (1932) writes of *P. africanus sundevallii*, but in some cases refers to the same animal as *P. africanus*. Furthermore, in some instances *P. africanus sundevallii* is referred to as a race and in other instances as a species. From the literature available it has been found impossible to determine the significance of these facts, but it is clear that there is some confusion on the subject.

Until recent years little was known concerning long extinct pigs of the wart-hog type. Zittel (1925) makes no reference to such pigs, and it seems that the first important discovery was made by Broom in 1925. In that year Broom reported on a new genus of giant pig from the late tertiaries of South Africa. This new genus he named *Notochoerus*. In the following year, 1926, Hopwood reported on another extinct genus, *Metridiochoerus*, while in 1932 Van Hoepen added four more genera, namely, *Kolpochoerus*, *Tapinochoerus*, *Synaptochoerus*, and *Stylochoerus*.

Use has been made of the teeth for distinguishing modern wart hogs, and these structures have proved of major importance for identifying extinct pigs. Nevertheless, evidence concerning the characters of the dentition in both modern and extinct pigs is inadequate, and there are several problems connected with the dentition of these animals which require further investigation. For example, evidence is lacking concerning certain of the characters of the incisor teeth of *Phacochoerus*. Owen (1845) stated that "in the wart hog of South Africa, *P. aethiopicus*," the incisor teeth are shed in the mature animal, while "in the northern wart hog, *P. africanus*," they are retained throughout life. Lydekker (1894) found no evidence in support of this conclusion, yet the same conclusion was arrived at by Sclater (1900). Lönnberg (1908) reported that both upper and lower incisors are shed in old members of the species *P. aethiopicus*,

but Van Hoepen (1932) found no evidence in support of either this or the earlier conclusion of Owen (1840–45). Sufficient data concerning the characters of the molars of *Phacochoerus* is also lacking. Lydekker (1885) stated it was impossible to distinguish the molars of *P. aethiopicus* from those of *P. africanus*, and Hinton, quoted by Hopwood (1926), reached the same conclusion. More recently, however, in 1932, Van Hoepen reported that "contrary to the general belief, there is a real difference between the teeth of *P. aethiopicus* and *P. africanus*. The third molars of *P. africanus* start forming roots long before all the columns have reached the triturating surface, while this is not the case with *P. aethiopicus*."

Differences of opinion also exist concerning the dentition of fossilized pigs. For example, Dreyer and Lyle (1931) as a result of investigating a number of teeth discovered at Florisbad, established four new species of extinct *Phacocheres*. Later, Van Hoepen (1932) brought forward evidence to show that these authors had incorrectly interpreted the significance of the characters of the Florisbad teeth and that their new species are synonyms of either *P. africanus* or *P. aethiopicus*. More recently, in 1938, it was shown by the writer that in the two species described by Broom, *N. capensis* and *N. meadowsi*, the third molars have fundamentally identical characters, and that the probabilities are that *N. meadowsi* is a synonym of *N. capensis*.

In addition to confusion concerning the names and lack of sufficient evidence concerning the dentition, there is diversity of opinion concerning the value of skull dimensions for identifying species and races of wart hogs. Lönnberg (1908) identified the five races previously referred to by differences in the relative proportions of their skulls and Van Hoepen (1932) adopted the same method. It has been shown, however, by Hollister (1924) that at least in the case of *P. massaicus* and *P. aeliani* Lönnberg's method is "too inconsistent and unreliable for systematic purposes."

The present writer recently gathered together a number of modern wart hog skulls with teeth *in situ*, a number of loose, modern, fossilized, or semi-fossilized wart hog third molars and three third molars of the *N. meadowsi* type. This material provided an opportunity for further investigation of some of the problems connected with the wart hog dentition, and the present report deals in particular with growth changes and variations in the third molars of modern wart hogs and the significance of these changes in relation to characters which have been identified in the third molars of extinct pigs. In addition there is a brief report on the dimensions of the skulls of modern wart hogs and on variations in the number of incisor teeth in these animals.

First, the dimensions of the modern skulls are discussed. Evidence was lacking concerning the identity of these skulls, but as zoologists state that *P. aethiopicus* is extinct it seemed probable that they belonged to the

species *P. africanus.* It was found, however, that a number of them have dimensions which differ markedly from those which previous investigators have considered characteristic of this species, and in view of this and Hollister's (1924) remarks concerning the inadequacy of skull proportions for identifying certain races of wart hog, it has been decided to record the dimensions of all the skulls in the collection. It will be shown that the relative proportions of skulls fail to provide a means of distinguishing *P. aethiopicus* from *P. africanus* and that there are reasons for doubting if such proportions assist in identifying other races or species of wart hog.

Secondly, the characters of the incisor teeth in the skulls are described. The material was not entirely suitable for investigating the problem of differences in the time of shedding of the incisors in *P. aethiopicus* and *P. africanus*, but, nevertheless, there emerged from investigation certain facts which are relevant to this subject, and in addition new evidence was secured concerning the normal number of lower incisors in *P. africanus*.

The remainder of the report is concerned with the third molars in modern and extinct wart hogs, and, as previously stated, special consideration is given to growth changes and variations in modern molars and the importance of these factors in relation to characters identified on the teeth of extinct pigs. For convenience of description the subject is considered under four main headings, as follows:—

1. The third molars of *P. africanus.*
2. Variations in the third molars of *P. africanus.*
3. Differences in the third molars of *P. africanus* and *P. aethiopicus.*
4. The significance of characters identified on the third molars of some extinct pigs.

## Material and Acknowledgments.

The material available consisted of twenty-nine complete skulls, two skulls without mandibles, three mandibles, and eleven loose molar teeth of modern African wart hogs; forty-one fossilized or semi-fossilized wart hog third molars, and three third molars of *N. meadowsi* (syn. *Notochoerus capensis*).

The majority of the modern skulls and teeth were borrowed for the purpose of the investigation. Three skulls were provided by Professor E. J. Van der Horst of our Department of Zoology. Dr. John Hewitt, Director of the Albany Museum, placed six skulls from his collection at my disposal. Dr. Pringle, of the Port Elizabeth Museum provided two skulls, and Messrs. Ivy, taxidermists, of Pretoria, eleven complete skulls, two skulls without mandibles and two odd mandibles. The remainder of the modern skulls and all the loose modern teeth belong to our Dental Anatomy

Museum. Professor Raymond A. Dart, and Dr. Alexander Galloway of our Department of Anatomy and Dr. John Hewitt provided the majority of the fossilized and semi-fossilized third molars, but a few of these teeth belong to the writer. I wish to place on record my appreciation of the kindness of Professors Dart and Van der Horst, Drs. Hewitt, Pringle, and Galloway, and Messrs. Ivy, in assisting the investigation by providing material.

## Geographical Classification of Material.

All the skulls obtained from Messrs. Ivy came from either the Transvaal, Portuguese East Africa, or Southern Rhodesia. These skulls are referred to in the text by the labels, P. 1, P. 2, P. 3, etc. The following particulars are available concerning the remainder of the material:—

Skull Alb. No. 1—In Albany Museum for over fifty years.
,, Alb. No. 2—Shot in Lebombo Mountains (Transvaal-Portuguese East African Border).
,, Alb. No. 3—From South West Africa.
,, Alb. No. 4—From Newington, Transvaal.
,, Alb. No. 5829—From M'Pika District of Northern Rhodesia.
,, Alb. No. 5—From Bakala Plateau of North Western Rhodesia.
,, SDA. 1—From Barberton, Transvaal.
,, SDA. 2—From Barberton, Transvaal.
,, SDA. 3—From South West Africa.
,, SDA. 4—From the Transvaal.
,, SDA. 5—From the Eastern Transvaal.
,, SDA. 6—From fhe Eastern Transvaal.
,, SDA. 7—From the Eastern Transvaal.

Particulars are lacking concerning the skulls Z. 2, and Z. 3 (from our Zoology Museum) and PE. 1 and PE. 2 (from Port Elizabeth Museum).

Mandible 1098—From the Eastern Transvaal.

Eleven third molars, DA. 1–11—From Transvaal wart hogs.

Six third molars, Nos. 896–A; 896–*4b*–896–*4c*; 896–*5b*; 896–A; 896–5—Discovered in a mineral spring at Florisbad, near Bloemfontein.

Five third molars, Nos. 830*b*; 832*b*; 832–A2; 832–B1; 830–B2—Discovered in Mumbwa Cave, Northern Rhodesia.

Eight third molars, Nos. A1; A1–2; A1–3; A1–4; A1–5; B1; B1–1; C2—Discovered at Mount Elgon, Kenya Colony.

One third molar, No. 951—Discovered in a cave at Stormberg, Cape Province.

One third molar, No. 866—Discovered at Senekal, Orange Free State.

One third molar, No. ES. 1—Discovered six feet below the surface at Winburg, Orange Free State.

One third molar, No. 909—Discovered in a cave at Rustenburg, Transvaal.

Two third molars, No. 982—Discovered at Kopjes, Orange Free State.

One third molar, No. 985—Discovered at Frankfort, Orange Free State.

One third molar, No. 4—Discovered in a cave at Cala, Cape Province.

One third molar, No. 6—Discovered in a cave at Lichtenburg, Transvaal.

Two third molars, No. 949—Discovered near Grahamstown, Cape Province.

Two third molars, No. 7 and 7A—Discovered in a shell mound on the farm Paardoolii (2 miles from the sea) in the Alexander District, Cape Province. "The mound contained stone implements of the middle stone age type." (Hewitt.)

One third molar, No. D. 12—Discovered in a cave at Rustenburg, Transvaal.

Four third molars, No. 334—Discovered at Venterstad, Cape Province.

One third molar, No. 3655—Discovered at Tarka Bridge, near Cradock, C.P.

One third molar, No. PE. 1—Discovered in the bed of the Vaal River.

One third molar, No. D. 11—Discovered at Oliphants Nek, Transvaal.

Three third molars of *N. capensis*—Discovered at Sterkfontein, Transvaal.

## Dimensions and Proportions of Wart Hog Skulls.

Difficulty was experienced in determining the landmarks used by Lönnberg (1908) and Van Hoepen (1932) when measuring wart hog skulls and it was therefore found necessary to seek information on this matter from the latter investigator. Dr. Van Hoepen was kind enough to provide the information that he also had difficulty in discovering the landmarks used by previous investigators, but that finally he had made use of the following:—

Length = From tip of snout, over the upper surface of the skull along the middle line up to the hinder rim of the upper surface.

Orbital Breadth = (Inter-orbital width). The shortest straight distance between the rim of the orbits over the upper surface.

Post-Orbital Length = The length, along the middle line over the upper surface, of a line connecting the hindermost points in the rims of both orbits, to the hinder edge of the upper surface.

Post-Orbital Width = The distance between the muscular ridges on the upper surface of the hinder end of the skull.

These landmarks were adopted by the present writer and were probably the ones used by Lönnberg (1908) but the evidence on this point is not clear. Both Lönnberg (1908) and Van Hoepen (1932) describe the post-orbital width as "a nearly worthless dimension since it depends on the greater or lesser development of the muscles of the jaw" (Van Hoepen).

The dimensions and relative proportions of the skulls in the writer's collection are set forth in the accompanying table (Table I). The skulls are arranged in this table according to what is considered to be their relative ages, the oldest skull being placed first and the youngest skull last on the

table. As the condition of the second molars was utilized in determining age, particulars of these teeth are also recorded in the table.

TABLE I.—*Measurements of Wart Hog Skulls.*

| Skull No. | Length in mm. | Inter-orbital width. | | Post-orbital length. | | Post-orbital width. | | Condition of M2. |
|---|---|---|---|---|---|---|---|---|
| | | mm. | Per cent. of length. | mm. | Per cent. of length. | mm. | Per cent. of length. | |
| Alb. 5 . | 425·0 | 136·0 | 32·0 | 55·0 | 12·9 | 46·0 | 10·8 | Shed: Trace of sockets. |
| Alb. 5829 | 392·0 | 142·0 | 36·2 | 44·5 | 11·3 | 41·5 | 10·5 | Shed: Trace of sockets. |
| Alb. 1 . | 408·0 | 131·0 | 32·1 | 52·0 | 12·7 | 46·5 | 11·3 | Shed: Trace of sockets. |
| Alb. 2 . | 386·0 | 134·0 | 34·7 | 49·0 | 12·6 | 41·5 | 10·7 | Shed: Trace of sockets. |
| SDA. 7 . | 352·0 | 127·0 | 36·0 | 38·0 | 10·7 | 44·0 | 12·5 | Almost shed. |
| P. 13 . | 387·0 | 136·0 | 35·1 | 44·5 | 11·4 | 43·5 | 11·2 | 4th degree attrition. |
| P. 3 . | 383·0 | 139·0 | 36·2 | 52·0 | 13·5 | 46·5 | 12·1 | 4th degree attrition. |
| SDA. 5 . | 370·0 | 113·0 | 30·5 | 56·0 | 15·1 | 35·0 | 9·4 | 4th degree attrition. |
| P. 4 . | | | | Skull | broken | | | 3rd–4th degree attrition. |
| P. 5 . | 395·0 | 124·0 | 31·3 | 57·0 | 14·4 | 37·0 | 9·3 | 3rd–4th degree attrition. |
| P. 1 . | 335·0 | 109·0 | 32·5 | 45·0 | 13·4 | 38·0 | 11·3 | 3rd–4th degree attrition. |
| Z. 1 . | 423·0 | 124·5 | 29·4 | 56·0 | 13·2 | 46·0 | 10·8 | 3rd–4th degree attrition. |
| P. 7 . | 352·0 | 102·0 | 28·9 | 45·0 | 12·7 | 21·0 | 5·9 | 3rd–4th degree attrition. |
| SDA. 1 . | 405·0 | 127·0 | 31·3 | 50·5 | 12·4 | 27·0 | 6·6 | 3rd–4th degree attrition. |
| PE. 372 . | 405·0 | 137·0 | 33·8 | 56·0 | 13·8 | 43·0 | 10·6 | 3rd–4th degree attrition. |
| Alb. 3 . | 360·0 | 108·0 | 30·0 | 52·0 | 14·4 | 36·5 | 10·1 | 3rd–4th degree attrition. |
| Z. 2 . | 353·0 | 115·0 | 32·5 | 45·0 | 12·7 | 39·0 | 11·0 | 3rd–4th degree attrition. |
| P. 12 . | 338·0 | 122·0 | 36·0 | 47·0 | 13·9 | 39·0 | 11·5 | 3rd–4th degree attrition. |
| SDA. 2 . | 336·0 | 100·0 | 29·7. | 51·0 | 15·1 | 35·0 | 10·4 | 3rd degree attrition. |
| SDA. 3 . | 347·0 | 115·0 | 33·1 | 45·5 | 13·1 | 37·5 | 10·8 | 2nd–3rd degree attrition. |
| SDA. 4 . | 391·0 | 126·0 | 32·2 | 55·5 | 14·1 | 38·5 | 9·8 | 2nd degree attrition. |
| P. 9 . | 385·0 | 112·0 | 29·0 | 52·0 | 13·5 | 49·0 | 12·7 | 2nd degree attrition. |
| P. 10 . | 332·0 | 101·0 | 30·4 | 45·5 | 13·7 | 35·0 | 10·5 | 2nd degree attrition. |
| P. 6 . | 354·0 | 110·0 | 31·0 | 41·0 | 11·5 | 43·0 | 12·1 | 1st–2nd degree attrition. |
| P. 8 . | 359·0 | 103·0 | 28·6 | 56·0 | 15·5 | 41·0 | 11·4 | 1st–2nd degree attrition. |
| P. 11 . | 349·0 | 105·0 | 30·0 | 52·0 | 14·9 | 40·0 | 11·4 | 1st degree attrition. |
| PE. 1 . | 345·0 | 106·0 | 30·7 | 43·0 | 12·4 | 29·0 | 8·4 | 1st degree attrition. |
| Z. 3 . | 354·0 | 106·0 | 29·9 | 57·0 | 16·1 | 35·0 | 9·8 | 1st degree attrition. |
| Alb. 4 . | 312·0 | | | Skull | broken | | | Recently erupted. |
| P. 2 . | 299·0 | 97·0 | 32·4 | 46·0 | 15·3 | 32·0 | 10·7 | Recently erupted. |
| SDA. 6 . | 217·0 | 66·0 | 30·4 | 31·0 | 14·2 | 28·5 | 13·1 | Recently erupted. |

Lönnberg (1932) records that "in the typical Cape wart hog" (*P. aethiopicus*) the proportions of the skull were as follows:—

| Race. | Percentage of total length of skull of | | |
|---|---|---|---|
| | Inter-orbital width. | Post-orbital length. | Post-orbital width. |
| *P. aethiopicus* . . . | 36·5 | 10·3 | 13·3 |

That is to say, the outstanding characters of the skull of this species is a short post-orbital length and a relatively wide inter-orbital width.

For reasons which have been explained when dealing with the names given to races and species of wart hog, it has been found difficult to discover the corresponding proportions for the species *P. africanus*. The following are Lönnberg's figures for five races of wart hogs, one of which is called *P. africanus* and which presumably is the same as the species of that name:—

| Race. | Percentage of total length of skull of | | |
|---|---|---|---|
| | Inter-orbital width. | Post-orbital length. | Post-orbital width. |
| *P. africanus* . . . . . | 30·0 | 13·4 | 13·1 |
| *P. aeliani* . . . . . | 31·0 | 15·4 | 6·3 |
| *P. massaicus* . . . . . | 38·3 | 14·0 | 14·5 |
| *P. sundevallii* . . . . | 32·3 | 13·7 | 11·0 |
| *P. delameri* . . . . . | 34·7 | 10·52 | 11·9 |

*P. africanus* is described by Lönnberg (1908) as "the largest or one of the largest of these races." As will be seen, it differs from *P. aethiopicus* by having a large post-orbital length and a relatively small inter-orbital width. It has very similar proportions to *P. sundevallii* which Lönnberg described as a Natal, Transvaal and Portuguese East African wart hog.

The corresponding proportions for five skulls investigated by Van Hoepen (1932) are as follows:—

| Skull. | Percentage of total length of skull of | | |
|---|---|---|---|
| | Inter-orbital width. | Post-orbital length. | Post-orbital width. |
| A. 1411 . . . . . | 36·3 | 11·4 | 8·1 |
| A. 1415 . . . . . | 32·9 | 13·5 | 8·4 |
| A. 1392 . . . . . | 33·9 | 13·8 | 7·9 |
| A. 1023 . . . . . | 30·3 | 15·0 | 10·7 |
| A. 1412 . . . . . | 33·8 | 14·3 | 11·3 |

Commenting on these figures, Van Hoepen says: "From this it appears that the skull of A. 1411 most closely resembles Lönnberg's measurements of *P. aethiopicus*, although his post-orbital width is much less. The root

alveolus of M. 2 is still present in this skull. It cannot therefore be old and this may be the cause of the smaller post-orbital width. The difference, however, is well marked. The skulls A. 1392, A. 1413, A. 1412 and A. 1023 all show a great resemblance to *P. africanus sundevallii*. The inter-orbital width of most of them is a little greater, but the post-orbital breadth of two is much smaller, probably because they are young." In the English summary of his Report Van Hoepen concludes that the skull A. 1411 represents *P. aethiopicus* and that his other four skulls represent *P. africanus sundevallii*.

Comparing now the proportions of Lönnberg's and Van Hoepen's skulls with those of the skulls in the writer's collection, and making allowance for variations in age, it is seen that while the majority of the latter have proportions which resemble those of either *P. africanus*, *P. sundevallii* or *P. africanus sundevallii*, there are a number of exceptions. For example, the skull 5829 corresponds in age and has dimensions which closely resemble those of Van Hoepen's *P. aethiopicus* skull A. 1411. This is clearly shown by the following comparison:—

| | Percentage of total length of skull of | | |
|---|---|---|---|
| | Inter-orbital width. | Post-orbital length. | Post-orbital width. |
| *P. aethiopicus* (Van Hoepen) . | 36·6 | 11·4 | 8·1 |
| Skull 5829 . . . . . | 36·2 | 11·3 | 10·5 |

It has already been pointed out that Van Hoepen and Lönnberg attach no value to the post-orbital width. The difference in this width in the writer's and Van Hoepen's skulls must therefore be regarded as of no significance. If, however, this dimension is disregarded the skull No. 5829 has proportions which are identical with those of Van Hoepen's skull No. A. 1411. That is to say, it has proportions which warrant the conclusion that it belongs to the species *P. aethiopicus*. As, however, it is a skull of a modern wart hog from the M'Pika district of Northern Rhodesia and *P. aethiopicus* is extinct, it is obviously impossible to accept this conclusion.

A similar difficulty arises in the case of the writer's skull SDA. 7. This skull lacks second molars in the lower jaw, but in the upper jaw traces of these teeth are still evident. It is, therefore, a slightly younger skull than Van Hoepen's *P. aethiopicus*. Its proportions are, however, of the *P. aethiopicus* type, and in fact they closely resemble those of the skull which Lönnberg (1908) described as a typical example of this species. The following figures confirm this view:—

| | Percentage of total length of skull of | | |
|---|---|---|---|
| | Inter-orbital width. | Post-orbital length. | Post-orbital width. |
| *P. aethiopicus* (Lönnberg) . | 36·5 | 10·3 | 13·3 |
| Skull SDA. 7 . . . . | 36·0 | 10·7 | 12·5 |

The skull SDA. 7 is, however, also a modern skull and in fact it belongs to an animal which was shot in the Eastern Transvaal, less than six months ago, by a friend of the writer.

The dimensions of the skulls P. 3 and P. 13 are also deserving of note. As is shown by the following comparison, they have proportions which resemble those of Lönnberg's *P. aeliani* and *P. delameri* skulls respectively:

| | Percentage of total length of skull of | | |
|---|---|---|---|
| | Inter-orbital width. | Post-orbital length. | Post-orbital width. |
| *P. aeliani* (Lönnberg) . . | 31·0 | 15·4 | 6·3 |
| P. 5 . . . . . . | 31·3 | 14·4 | 9·3 |
| *P. delameri* (Lönnberg) . . | 34·7 | 10·5 | 11·9 |
| P. 13 . . . . . . | 35·1 | 11·4 | 11·2 |

Finally, it must be noted that a few skulls, *e.g.* P. 12, have proportions which are distinctly different from those of any of Lönnberg's or Van Hoepen's specimens and, moreover, are different from the proportions recorded by other investigators for wart hog skulls. If Lönnberg is correct in stating that wart hogs can be identified from their skull proportions, it is impossible satisfactorily to explain these facts. There is now, however, considerable evidence to show that the conclusion of this investigator is incorrect. As already pointed out, Hollister (1926) found the relative proportions of skulls too unreliable for distinguishing *P. massaicus* from *P. aeliani*. There is every reason to believe that zoologists are correct in stating that *P. aethiopicus* is extinct; and since, moreover, as will be shown later, teeth of the *P. aethiopicus* type are not present in any of the skulls in the writer's collection, it is impossible for the skulls Nos. 5829 and SDA. 7 to represent this species. That is to say, in the case of *P. aethiopicus* also skull proportions are too unreliable for systematic purposes. It is possible that the races *P. aeliani* and *P. delameri* are represented, but since these are

races found in Abyssinia and British East Africa, and the skulls P. 5 and P. 13 probably belong to Transvaal or Rhodesian wart hogs, it is extremely unlikely that this is the case.

The subject is obviously one which requires further investigation, but meanwhile the following conclusions are warranted from the data secured:—

1. Skull proportions fail to identify *P. aethiopicus*.
2. There is evidence to show that in the case of both races and species of wart hogs skull proportions are too inconsistent and unreliable for systematic purposes. Nevertheless:—
3. Since *P. aethiopicus* is extinct, and all the skulls (with the exception of the skull Alb. 1, which has been in the Albany Museum for over fifty years) belong to modern wart hogs they must be considered to represent the living species *P. africanus*.

A further conclusion is also warranted, namely, that there is immense individual variation in the dimensions of wart hog skulls within a single species.

## The Incisor Teeth of *P. Africanus*.

The number of incisors in the wart hog *Phacochoerus* has hitherto been considered to be two in the premaxilla and six in the mandible, but, as already pointed out, it is uncertain whether all of these teeth are retained throughout life in both species.

A number of the older *P. africanus* skulls in the writer's collection lack one or two upper or lower incisors. Unfortunately, although it may appear to be an easy matter to determine, in many cases it was found difficult to decide if absent teeth had been lost before or after death. Finally, it was concluded that where upper incisors were absent, they had been lost post mortem. It was found, however, that in several skulls the existing upper incisors were severely worn away by attrition and their sockets, as revealed by X-Rays, were exceedingly short. It seems probable therefore that with further attrition and shallowing of the sockets some of these teeth would have been shed. Evidence is therefore available in support of the view that the incisors of the upper jaw are shed in old representatives of the modern wart hog *P. africanus*. In five old specimens there is conclusive evidence that lower incisors were shed before death. In three of these specimens all the lower incisors are absent; in another specimen the third or outer incisors and in the fifth specimen the second and third outer incisors are absent. It is evident, therefore, that shedding of the lower incisors in old age is also a character of the dentition of *P. africanus*. In addition, however, it was found that in some cases six lower incisors are not developed in this species. In six skulls, namely P. 6, P. 8, P. 10, DA. 2,

P. 4 and Z. 1, only four lower incisors are present. As will be seen from Table I, the three former skulls belong to fairly young animals, DA. 2 belongs to an older animal, while the two latter skulls belong to fully developed animals. It is possible that in the skulls Z. 1 and P. 4 lower incisors were shed during life, but there is not the slightest indication that this occurred and it appears most improbable. It is still more improbable that incisors were shed during life in the younger skulls, for shedding is an occurrence which takes place in old animals only. The possibility that complete eruption of the lower incisors has not yet taken place was removed when radiographical examination failed to reveal any evidence of unerupted incisors. It must therefore be concluded that four is the normal number of incisors in the animals represented by these skulls. The incisor formula of *P. africanus* must therefore be regarded as subject to variation and should in future be written I. $\frac{1}{2\text{-}3}$ and not, as formerly, I. $\frac{1}{3}$.

### The Third Molars of *P. africanus*.

#### (a) *General Characters.*

The following description of the wart hog third molar is taken from Owen's Odontography (1840–45):—

> "The third and last true molar is the most characteristic tooth of the *Phacocheres*, and perhaps the most peculiar and complex tooth in the whole class of Mammalia: the surface of the crown in the specimen before me measures two inches in antero-posterior extent and eight lines in transverse breadth, and presents three series of enamel islands, in the direction of the long axis of the grinding surface; the middle row of eight islands are elliptic and simple; those of the outer rows are in equal number, but are sometimes subdivided into small islands; these islands or lobes are the abraded ends of long and slender columns of dentine, encased by thick enamel, and the whole blended into a coherent crown by abundant cement, which fills up all the interspaces and forms a thick exterior investment of the entire complex tooth. . . . The formative matrix continues for a long period to be reproduced, maintaining by its successive calcification the crown of the tooth entire to the bottom of the sockets, where the orifices of the constituent cylinder and the vacant interspaces, which lodged the complex vascular matrix, are seen in the dried tooth."

This description has been quoted in full for, although it was written nearly a century ago, it remains the best description of the wart hog third molar which the writer has been able to discover in the fairly extensive

literature on the subject which is available. Unfortunately, while it describes adequately the general characters of wart hog third molars and states the features which are presented by a particular tooth at a particular stage of development, it fails entirely to explain the special characters presented by third molars at different stages of attrition and growth. Unlike the teeth of the majority of mammals the third molars of the wart hog are subjected to very great attrition and grow from semi-persistent pulps. As a result of attrition the form of their occlusal surfaces is constantly changing, while due to their semi-persistent pulps they are growing at their base until a fairly late period of life and new calcific material is constantly being deposited at this situation by the formative cells of the pulp. Previous reports on these teeth have failed to take these factors into account, and as a consequence the descriptions available are both inadequate and misleading.

### (b) *Growth Changes and Attrition.*

No useful purpose would be served by describing minute changes which occur during the course of development and attrition, but it is proposed to describe the characters presented by third molars at stages which are considered of particular interest and importance. The lower third molars in the collection of modern skulls have been made use of for this purpose.

Figs. 1 and 2 illustrate nine selected stages of third molar development. In both figures the specimens A to I represent every necessary stage from early youth (A) to senile old age (I). Fig. 1 is an occlusal and fig. 2 a lateral view of the nine specimens. In fig. 1 the distal ends of the teeth are at the top and the mesial ends at the bottom of the illustration, while in fig. 2 the anterior margins are to the right side in each tooth.

The specimen A (figs. 1 and 2) was removed from a skull in which the deciduous molars were still *in situ*. This tooth is, therefore, an unerupted third molar. It measures 23 mm. mesio-distally, 11 mm. labio-lingually (at its widest part) and has a maximum vertical height of 35 mm. The columns are open at their base and closed and unworn at their occlusal ends. They are not regularly arranged, but nevertheless it is possible to group them into three series or rows, namely, an outer or buccal row, an inner or lingual row, and a median row. There are four columns in the buccal row, an equal number in the lingual row, and seven columns in the median row. With the exception of the first and last, which are situated externally at the mesial and distal extremities, the median columns can only be identified at the base of the tooth. On the occlusal surface these columns are overlapped by the marginal columns and by the cementum

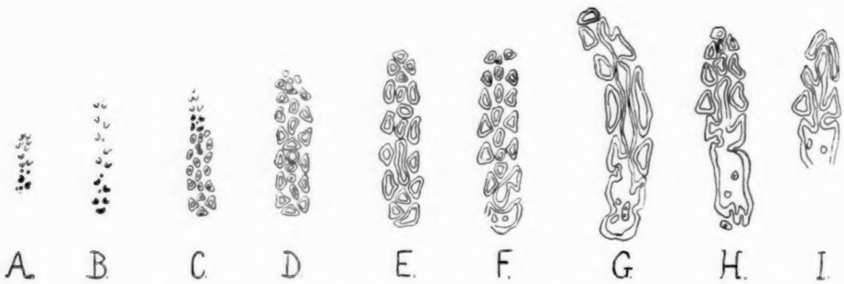


FIG. 1.—Nine stages in the development of lower third molars. Occlusal view. (See also fig. 2.)

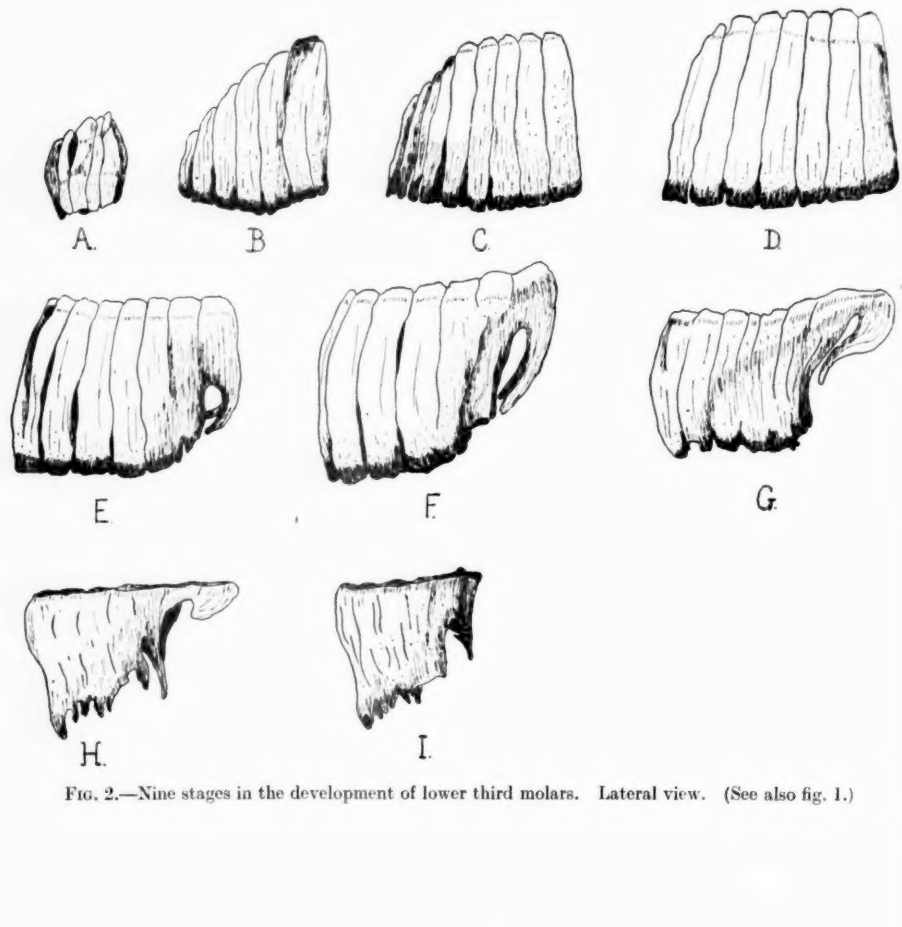


FIG. 2.—Nine stages in the development of lower third molars. Lateral view. (See also fig. 1.)

which fills up the interspaces. They become evident on the occlusal surface after wear has taken place. Viewed from the side (fig. 2) the columns of the anterior end are seen to be slightly taller than the columns situated more distally. That is to say, the height of the columns (and of the tooth) decreases from front to back and the greatest vertical height of the tooth is at its anterior end.

The specimen B is also an unerupted tooth, but it is more advanced in development than A. It is in fact a third molar which was about to erupt. It differs from the latter in the following respects: It is a larger tooth. Its mesio-distal length is 37 mm., its greatest width 11 mm., and its greatest height 45 mm. Its columns are regularly arranged in three rows—buccal, lingual and median. The anterior columns are markedly taller than the distal columns, and as a consequence when viewed from the side the tooth has a triangular shape. It has six buccal, six lingual and six median columns, and as in A the latter are hidden on the occlusal surface.

The tooth C measures 50 mm. mesio-distally, 12 mm. labio-lingually, and 47 mm. vertically (at the mesial end). Its anterior two-thirds had erupted when the specimen was removed from its socket, but the posterior third was still enclosed in the socket. The occlusal surface of the anterior two-thirds presents three series or rows of dentine-enamel islands in the direction of the long axis of the tooth. These islands are the abraded ends of the columns, and it is to be noted that it is only at this stage, *i.e.* after attrition has taken place, that the columns of the median series are seen on the occlusal surface. As in B, the columns at the mesial end are taller than those situated distally. Whereas, however, in the former tooth the columns decreased in size from front to back, in C the first five columns have approximately the same vertical height and a decrease in height only occurs in the distal third of the tooth. That is to say, the erupted, abraded columns correspond in height, while only the unerupted and unworn columns decrease in height from front to back. There are eight buccal, eight lingual and twelve median columns, and of these five buccal, six lingual and nine median are represented by islands on the abraded occlusal surface. When viewed from the side (fig. 2) the columns are seen to be wider mesio-distally at their basal than at their occlusal ends. This, however, is not a conspicuous feature until the next stage of development *vide* (fig. 2, D).

The specimen D is a fully erupted tooth, and with the exception of one or two distal median columns, which are still below the level of the masticatory surface, all its columns are represented on the occlusal surface by dentine-enamel islands. The columns have approximately the same height, and a lateral view of the tooth now resembles a four-sided figure.

The following are the principal dimensions of this tooth:—

| | |
|---|---|
| Mesio-distal diameter at base . . . . . . | 60 mm. |
| ,, ,, ,, occlusal surface . . . | 48 mm. |
| Vertical height (at both mesial and distal ends) . . | 49 mm. |
| Greatest width at occlusal surface. . . . . . | 12 mm. |

Seven buccal, seven lingual and eleven median columns are present, and a number of the islands which represent them on the occlusal surface are different in form and size to the islands of C. Further changes in the size and form of the occlusal islands will be seen in the teeth selected to illustrate later stages of development of the third molars, and it is necessary therefore to explain why these changes come about.

The columns which make up a wart hog third molar vary in size in different teeth of corresponding age, in different parts of the same tooth and in teeth of different ages. In young teeth each column has approximately the same diameter at its occlusal and basal end and all the columns are quite separate and distinct throughout their entire vertical height (fig. 1, A). In slightly older teeth the columns widen out at their bases and thus become roughly cone-shaped. In old teeth adjoining columns unite and thus give rise to a smaller number of more complex-shaped columns.

When attrition commences it wears away the tips of the columns and the occlusal surface, then presents a number of small, round, dentine-enamel islands (fig. 1, C). As attrition proceeds it exposes wider portions of each column, *i.e.* a lower level of each cone, and thus the islands increase in size, and many of them assume an oval, triangular or irregular form (fig. 1, D). Finally, when attrition exposes union of the columns, the occlusal islands display further complexity in form and further increase in size (fig. 1, E–I).

In D (fig. 1) attrition has not exposed union of columns, but it has exposed a wider portion of each column than was exposed in C, and as a consequence the occlusal islands are now oval or triangular in form.

The next stage of development is illustrated by E. This tooth differs from D in the following respects: All its columns are represented by islands on the occlusal surface—in D a few distal median columns are below the level of this surface. The islands are even larger than in D and some of them now present complex forms. For example, in the anterior half of the specimen there is a large oblong-shaped island, while at the anterior extremity a triangular-shaped island is present (fig. 1). As was explained when describing the specimen C, these changes in the form of the columns are due to attrition having worn down the tooth to a level at which some of its columns have lost their separate identity by fusing with adjoining columns. The oblong-shaped island is the result of fusion of the third and fourth median columns, while the triangular-shaped island has resulted

from union of the first median and first buccal columns. There are six buccal and six lingual marginal islands (including as a marginal the anterior triangular-shaped island) and seven median islands. Before wear had advanced, however, to the stage now exhibited, *i.e.* before union of the columns occurred, there were six buccal, six lingual, and nine median islands. Even this is a smaller number of islands than is exhibited by D, and these two teeth therefore illustrate a fact which is constantly demonstrated by the teeth investigated, namely, that the number of columns (and islands) varies markedly in different teeth. Perhaps, however, the most remarkable difference between the specimens D and E is that on the latter the anterior group of columns are markedly shorter than the remaining columns and they terminate in roots. Roots play an important part in the further development of wart hog third molars. It is necessary therefore to digress again to explain how, and when, these structures have their origin and the effect of their presence.

The third molars of the wart hog grow from semi-persistent pulps (*vide* Owen's description of the third molars, p. 62). Mummery (1924) describes a persistent pulp as follows:—

> "Persistent pulps are found in teeth which are subjected to constant and severe attrition, as the incisors of Rodents. The pulp is not completely enclosed within a bony cavity as in the majority of teeth, but remains open at the base and is continually growing during the life of the animal, new hard tissue being deposited by the formative cells of the pulp as the tip of the tooth becomes worn down by use."

In some animals the teeth have persistent pulps until after the teeth come into use, but they eventually become enclosed and roots are then developed. These are called semi-persistent pulps and, as stated above, are the type of pulp found in wart hog third molars.

The material investigated by the writer demonstrates that, in the modern wart hog *P. africanus*, enclosure of the pulp and development of roots commence at about the same time as eruption of the columns is completed on the occlusal surface. This fact is of importance and will be referred to again when dealing with differences in the third molars of *P. africanus* and *P. aethiopicus*. At first, enclosure of the pulp and development of roots occurs on only the anterior group of columns. The anterior roots are then short, but gradually they increase in size, and as they do so they decrease the height of the anterior group of columns. At a slightly later stage of development enclosure of the pulp and development of roots takes place on the second group of columns. Still later the pulps of the third and fourth group of columns, and eventually all the pulps become enclosed. Roots appear on each column shortly after the pulp becomes

enclosed, but normally the anterior roots are markedly larger and more regularly formed than the remaining roots. Decrease in the height of the columns follows the development of roots, and is also most marked in the case of the anterior group of columns.

The specimen E represents a stage where roots are present at the base of the anterior group of columns, and there is a tendency for root development at the base of the second group of columns. That is to say, this tooth represents an early but by no means the earliest stage of root development.

The following are the dimensions of E:—

| | |
|---|---|
| Mesio-distal length of the occlusal surface . . | 49 mm. |
| Labio-lingual width of the occlusal surface . . | 12 mm. |
| Greatest height (distally). . . . . . . | 46 mm. |

There is no marked difference in the age of the specimens E and F, but the latter is more severely abraded and consequently its occlusal surface presents a larger number of complex-shaped islands. In addition, it illustrates a slightly later stage of root development.

At the anterior end of F union has occurred between the first buccal, first lingual and first median columns, and these columns are therefore no longer represented on the occlusal surface by three separate islands, but by one complex-shaped island. This anterior complex island is a conspicuous feature on many wart hog third molars, and Van Hoepen (1932) called it the "anterior complex." This name has been adopted in the present report. Union of two other columns, namely, the second median and the second buccal column, is also exhibited by F. There is no evidence of union of the third and fourth median columns such as was seen in E, and in fact it was found that except in the case of the anterior group of columns, which are normally among the first to unite, union of the columns follows no order or arrangement.

The anterior roots on F are markedly longer and the anterior columns shorter than in E, while on F the second group of columns are also shorter and they exhibit fairly well-formed roots. At the base of the third and fourth group of columns the commencement of root development may be identified. The following are the dimensions of F:—

| | |
|---|---|
| Mesio-distal length at occlusal surface . . | 56 mm. |
| Maximum width of occlusal surface . . | 15 mm. |
| Vertical height (at distal end) . . . | 45 mm. |

In the next stage of development, illustrated by G, a number of important characters must be noted. The anterior complex comprises almost half the occlusal surface. In the distal portion all the median columns, with the exception of one situated at the distal extremity, are united, while

further union between some of the marginal and between some of the median and marginal columns is also exhibited. The marginals which are still separate are large and the mesio-distal diameter of the occlusal surface of the specimen is 59 mm. compared to 56 mm. in F.

Equally striking changes may be observed when the tooth is viewed from the side (fig. 2). Most of the columns have lost their identity, and as a consequence the sides of the tooth which in previous specimens were corrugated are now smooth. Roots are still present on the anterior group of columns, but these columns are fused together into one solid mass and have a vertical height of only 15–17 mm. The second group of columns are also short and possess roots, and at the bases of the remaining columns roots are also present. The maximum height of the tooth is 37 mm.

The lower molar (H), selected to represent the next stage of development, was opposed in the upper jaw by a tooth which had been injured during life. The occlusion of this tooth was therefore abnormal, and as a result, although it is an older tooth than G, the distal portion of its occlusal surface presents fewer united columns. Nevertheless, if allowance is made for individual variations of teeth and for the fact that union of columns normally follows no fixed order, the specimen can be accepted as fairly typical. On its occlusal surface it shows an exceedingly large anterior complex, portion of which has broken away. Distally, a number of marginal and median columns are separate, but the majority of the columns have become part of the anterior complex. As preserved, the specimen measures 57 mm. at its occlusal surface, but prior to loss of the anterior extremity this surface probably measured 59 mm. Except for these minor differences the occlusal surface of the specimens G and H are similar. The lateral view of H, however, presents several distinguishing characters. Most conspicuous of these is the absence of anterior roots which, at this stage, are shed. The anterior columns are even shorter than in G, and in fact they are almost entirely worn away. The distal portion exhibits roots, and on the sides of the tooth there is no longer any evidence of the former existence of separate columns. That is to say, the sides present a smooth, flat surface. The following are the principal dimensions of the specimen H:—

| | |
|---|---|
| Mesio-distal diameter at occlusal surface . | 57 mm. |
| Greatest vertical height . . . . | 38 mm. |
| Greatest width (labio-lingual) . . . | 14 mm. |

The last stage of development illustrated by the material at the writer's disposal is represented by I. On this tooth the anterior columns are entirely worn away, and as a consequence the mesio-distal length of the specimen is so shortened as to resemble that of the young specimen B (fig. 2). This

is the only conspicuous difference between the specimens H and I, but the latter shows in addition further shortening of its distal columns. In some specimens of corresponding age the entire occlusal surface exhibits a "complex," but in I a number of separate islands are still present. The following are the dimensions of I:—

| | |
|---|---|
| Greatest length at occlusal surface . . . | 37 mm. |
| Greatest vertical height (distally) . . . | 44 mm. |

It is probable that as a result of further attrition this tooth would have become shorter both mesio-distally and vertically. It is even possible that in time it would become almost entirely absorbed. Teeth showing this character were not, however, present in the writer's collection, and since with further attrition and consequent partial disappearance of the tooth mastication would have become almost impossible, it is probable that later stages of development than that represented by I are only very rarely met with.

### (c) *Concluding Remarks on Growth and Attrition.*

Although the above description of growth and wear changes is fairly comprehensive, it is necessary to state that it does not provide a complete account of all the forms which wart hog third molars may assume. As growth takes place until late in life and attrition only terminates on the death of the animal or disappearance of the teeth, the third molars must vary in form within very brief age intervals. Since only lower third molars have been dealt with and these teeth have slightly different anatomical characters to corresponding upper molars, it is obvious that an extensive range of variations must be expected. There is no doubt, however, that upper as well as lower third molars pass through stages of growth and attrition corresponding to those illustrated and described. Consequently, there should be no difficulty in determining the significance of any growth or wear variations which any third molar may present. There are, however, other types of variations which occur. These must now be described.

## Variations in the Third Molars of *P. africanus*.

In addition to variations which are the result of growth and attrition, variations occur which can be described under the following three headings, namely:—

(*a*) Variations in the number of rows of columns.

(*b*) Normal variations in the number, arrangement and form of the columns, and

(c) Differences between upper and lower third molars.

(a) *Variations in the Number of rows of Columns.*

When dealing with the general characters of the third molars it was shown that Owen (1845) described these teeth as "presenting three series of enamel islands in the direction of the long axis of the grinding surface." With certain minor modifications, which will be referred to under arrangement of the columns, this description applies to all the third molars so far described, and in fact to the third molars of the vast majority of wart hogs. As is shown, however, by the teeth illustrated in fig. 3 (*a*) 1, (*b*) 1, and

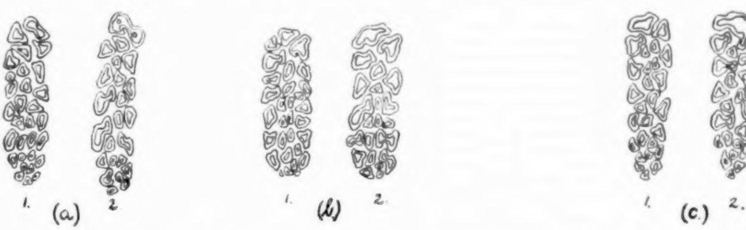


FIG. 3.—To illustrate the result of sectioning third molars which possess 4 instead of the normal number of 3 rows of columns. (*a*) 1, (*b*) 1, and (*c*) 1 illustrate the existing occlusal surfaces of three third molars, while (*a*) 2, (*b*) 2, and (*c*) 2, respectively, show the patterns revealed when sections were cut from the same teeth. Each section was cut 5–10 mm. below the existing occlusal surface.

(*c*) 1, in some rare cases there are four instead of three rows of columns. Only six of the specimens examined by the writer exhibit this condition, and in three of these two rows of median columns are present in parts of the teeth only. The specimen (*a*) 1 in fig. 3 shows four series in its distal third; in (*b*) 1, of the same figure, four series are present in the distal half, while in (*c*) 1, four rows of columns are present in only the anterior third.

Severely abraded teeth with four rows of columns are absent from the writer's collection, but there is no doubt that teeth with this number of rows become abraded in a manner similar to that described when dealing with teeth with three rows of columns. Moreover, union of columns also occurs in teeth with four rows. It was found, however, by sectioning young teeth with four rows that when union of their columns is exposed by attrition the resulting islands on the occlusal surfaces have a strikingly different form from those in teeth with only three rows. Fig. 3 (*a*) 2, (*b*) 2, and (*c*) 2 illustrate the condition found on sectioning the teeth whose occlusal surfaces are shown in fig. 3 (*a*) 1, (*b*) 1, and (*c*) 1, respectively. These sections were taken about 5–10 mm. below the level of the existing occlusal surfaces and illustrate therefore the characters which further abrasion would have disclosed. They demonstrate that in the body of teeth with four rows of columns union occurs between some of the buccal median and buccal

marginal columns and also between some of the lingual median and lingual marginal columns. As a result very complex-shaped marginal islands appear while the former existence of two rows of median columns ceases to be apparent. The original median islands are in fact now represented by prolongations of the marginal islands. In some cases these prolongations appear as antero-median extensions of the marginals while in other cases they appear as median or median transverse extensions of the same islands. As might be expected, however, from the complex-shaped islands which result from fusion in teeth with a single row of median columns the presence of two rows leads to a great variety of prolongations and consequent complex patterns on the occlusal surface. This fact is of major importance in connection with characters identified in fossilized teeth. So far as the writer is aware, the condition of two rows of median columns in the third molars of modern wart hogs has not previously been described.

### (b) *Normal Variations in the Number, Arrangement and Form of the Columns.*

In his Report, "Vrystaatse Wilde Varke," Van Hoepen (1932) describes in detail variations in the form, number and arrangement of the columns of third molars. A relatively small number of teeth were at his disposal, and his extremely detailed description of these variations occupy almost half of the sixty pages of the Report. To describe in similar detail the corresponding variations in the material now investigated is unnecessary. In third molars of different wart hogs and even in third molars from corresponding upper and lower jaws the columns normally vary slightly and sometimes vary markedly in their form, their number and arrangement. They fail therefore to provide evidence of value in respect of the problems here being considered. While, however, no classificatory purpose would be served by a detailed description of what are really normal variations of the columns, a few facts connected with the subject are deserving of record. The following remarks apply only to teeth with three rows of columns and, moreover, have special reference to the conditions of the columns as they are seen in fully erupted and abraded teeth.

*Number of Columns.*—In lower molars the average number of columns is seven buccal, seven lingual, and eight median, but the marginals vary from six to nine and the medians from seven to thirteen. In upper molars seven is the average number of columns in each of the three series, but the marginals vary from six to ten and the medians from seven to thirteen. In the majority of cases the columns on the buccal and lingual sides are of equal number, but in some cases more columns are present on one side than on the other. Supernumerary columns are occasionally present. These are of small size

and are situated outside the marginal columns. They are usually shorter than the marginals and consequently, until attrition is far advanced, fail to appear on the occlusal surface. They appear then as supernumerary islands. They are similar to the supernumerary elements sometimes found on human molars and described by Bolk (1916) as "paramolars." They have been recognised on the third molars of some extinct pigs, but apparently until now their presence on the corresponding teeth of modern wart hogs has escaped notice. As will be shown later, this has resulted in their acceptance as distinguishing characters of a certain genus of extinct pig. There is no doubt, however, that, as in the human dentition, they are anomalies which have only individual significance.

*Arrangement of the Columns.*—It is customary to say that the columns are arranged in three (or four) rows. Although this custom is not strictly

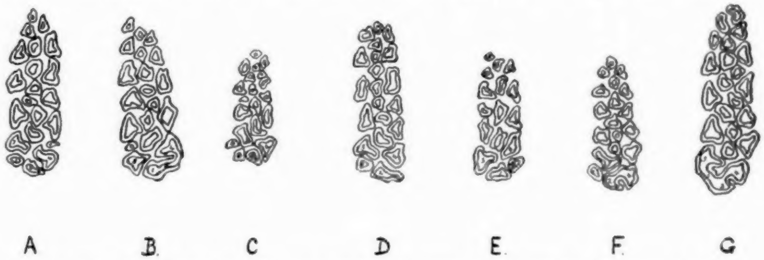


FIG. 4.—To illustrate that the anterior end of upper third molars is formed by four marginal columns. A–G represents the occlusal surfaces of seven specimens. In each specimen the four anterior marginal columns are distinguished by the figures 1, 2, 3 and 4.

accurate, it is convenient and has been adopted in the present report. It is necessary here, however, to point out that at the extremities of third molars this arrangement of columns is absent. At the distal end of both upper and lower molars there are usually either one median or two marginal columns. On account of their situation these columns have been referred to by previous investigators as "distal columns," but it seems preferable to regard them as columns of the marginal or median series. According to Van Hoepen (1932) one column at the distal extremity is the normal condition in old third molars. The writer's material fails to confirm this view.

In all the lower third molars investigated one median column formed the anterior extremity. On the other hand, the corresponding extremity of an upper molar is formed by two marginal columns and distal to these there are two more marginal columns. That is to say, the mesial end of an upper molar is formed by four marginal columns and at this situation median columns are not present. Unfortunately, it is frequently difficult

to recognize this arrangement, and Van Hoepen (1932), for example, frequently described an upper molar as terminating anteriorly in one median column. The difficulty arises due to the fact that in some instances the mesial end of upper third molars inclines lingually, thus disturbing the normal relation of the columns. Reference to fig. 4 will prove the writer's view to be correct.

*The Form of the Columns.*—The form of the columns is so closely associated with attrition that little can be added to what has already been said when dealing with growth and wear changes. It may, however, be stressed again that the columns are cone-shaped, but they are not all cones of equal size and many of them are irregularly formed. It follows, therefore, that in different teeth and in different parts of the same tooth small, large, round, oval, triangular and other shaped islands may be found on the abraded occlusal surface. In the great majority of cases the enamel of the columns has a smooth surface, but in some cases enamel with crenated, wrinkled or folded edges is exhibited. In teeth with enamel of this type the islands on the occlusal surface, *i.e.* the abraded ends of the columns, frequently present indentations, convexities and concavities which add considerably to the complexity of the form of the columns and of the occlusal surfaces.

### (c) *Differences between Upper and Lower Third Molars.*

It is convenient to refer here to differences between upper and lower third molars.

At first sight these teeth appear identical, but close investigation discloses a number of differences. For example, the uppers are normally wider labio-lingually than the lowers. It is considered, however, that no useful purpose would be served by describing minute differences of this nature, and it is therefore proposed to refer only to those differences which assist in identifying loose upper and lower third molars. Van Hoepen (1932) pointed out one method of doing this. He showed that in an upper molar "the second left or right side cone protrudes further from the tooth than any of the other side cones" while in a lower molar no one cone protrudes further outwards than the others. In the writer's experience this method is extremely satisfactory, but as in some cases the degree of protrusion of the second cone is very slight and thus not easily recognisable, it is desirable to have some additional method. Such a method is available as was indicated when dealing with "Normal variations in the number, arrangement and form of the columns."

The presence of four marginal columns and the absence of median columns at the anterior portion will in all cases identify an upper third

molar. Alternatively, the presence of only one median column at the anterior extremity will identify a lower third molar.

### DIFFERENCES IN THE THIRD MOLARS OF *P. africanus* AND *P. aethiopicus* (fig. 5).

When dealing with growth changes in the third molars of *P. africanus*, it was stated that roots develop on these teeth about the same time as

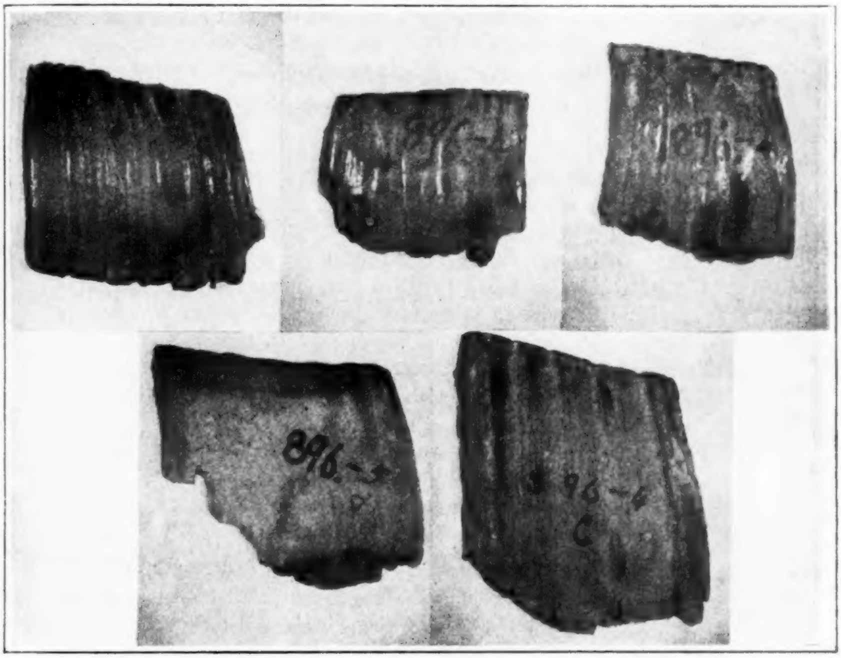


FIG. 5.—To show the form of some of the *P. aethiopicus* teeth in the writer's collection.

eruption of the columns on the masticatory surface is completed. Until Van Hoepen (1932) investigated the subject it was generally believed that this relation between root development and column eruption was also found in the third molars of *P. aethiopicus*. Van Hoepen (1932), however, brought forward evidence to show that it was only in *P. africanus* that root development coincides with the eruption of the columns and that in *P. aethiopicus* the development of roots occurs long after the last of the

columns have appeared on the triturating surface. "For the palaeontologist," he stated, "this result means that teeth with all their columns on the triturating surface and without roots belong to the *P. aethiopicus* group, while teeth in which the columns have only partially reached the triturating surface and which have closed columns or roots belong to the *P. africanus* group."

The evidence advanced in support of this view is extremely convincing; but as Van Hoepen stated that very limited material was at his disposal and his conclusion might be modified as a result of further investigation, it has been decided to inquire if the material now available throws any additional light on the subject.

The loose modern, semi-fossilized, and fossilized wart hog third molars were utilized for this inquiry and it was found as follows:—

(*a*) A number of these teeth belong to young animals. They possess neither roots nor fully erupted columns, and are therefore unsuitable for investigating the present subject.

(*b*) The eleven modern third molars and two semi-fossilized third molars have roots and fully erupted columns. The degree of root development compared to the degree of wear of the columns is similar to that seen in several of the third molars which were removed by the writer from the modern *P. africanus* skulls.

(*c*) Three semi-fossilized third molars show the commencement of root development coinciding with the completion of eruption of the columns on the masticatory surface.

(*d*) Two semi-fossilized third molars have both roots and fully erupted columns. Although, however, the columns are severely abraded and on both specimens the anterior complex is formed, the roots are small and are present on the anterior columns only. That is to say, in these two specimens the degree of root development compared to the degree of wear of the columns is markedly different from that seen in any of the third molars of the *P. africanus'* skulls.

(*e*) The remaining specimens, with the exception of a few which are damaged and unsuitable for investigation, have their columns fully erupted and, in most cases, severely abraded, but they lack roots.

It is clear from these facts that it is possible to distinguish the differences in wart hog third molars noted by Van Hoepen (1932). That is to say, it is possible to identify (1) teeth with all their columns on the triturating surface and without roots, and (2) teeth in which the columns have only partially reached the triturating surface and which possess

roots. It is also clear that while among modern third molars only the latter condition is found, in corresponding ancient teeth both conditions are exhibited. It is warranted to conclude that teeth with similar characters represent the same species. The modern and semi-fossilized teeth in groups (*b*) and (*c*) have characters similar to those found in the third molars of the *P. africanus* skulls. It is probable, therefore, that these teeth represent the species *P. africanus*. Obviously, however, the teeth in groups (*d*) and (*e*) are not third molars of the *P. africanus* type. They have, however, the characters which Van Hoepen (1932) found in the third molars of a *P. aethiopicus* skull, and in view of this it is extremely probable that they represent this species. The investigation, therefore, supports Van Hoepen's view concerning differences in the third molars of *P. aethiopicus* and *P. africanus*. In addition, since the *P. aethiopicus* type of third molar was not found in the modern skulls investigated, it confirms the writer's opinion that these skulls represent *P. africanus*.

Van Hoepen (1932) reported on a further slight difference in the third molars of *P. africanus* and *P. aethiopicus*. He stated that in the third molars of the latter the sides of the columns are parallel and fail to broaden out at their bases as they do in *P. africanus*. The writer's material fails to confirm this view, but it was found that broadening of the bases of the columns occurs at a later stage on *P. aethiopicus* than in *P. africanus*. The investigation showed in fact that the third molars of *P. aethiopicus* and *P. africanus* have the same characters, but whereas in the latter species certain characters develop early, in *P. aethiopicus* these characters fail to develop until late in life.

### The Significance of Characters Identified on the Third Molars of Some Extinct Pigs.

With the assistance of the data secured from investigation of the third molars of *P. africanus* and *P. aethiopicus* it is now proposed to review the evidence which has resulted in the establishment of the extinct species *Phacochoerus laticolumnatus* and the extinct genera *Stylochoerus*, *Synaptochoerus*, *Tapinochoerus* and *Kolpochoerus*. In addition, the characters of the third molars of *N. capensis* (syn. *N. meadowsi*) will be reconsidered.

Unfortunately, neither the originals nor models of the teeth of *P. laticolumnatus*, *Stylochoerus*, *Synaptochoerus*, *Tapinochoerus* or *Kolpochoerus* are available to the writer and consequently for an understanding of the characters of these teeth it has been found necessary to rely entirely on the descriptions and illustrations provided in Van Hoepen's (1932) Report. The latter is written in Afrikaans and as the writer is not fully conversant with this language it was frequently found necessary to make

use of a translation prepared by Dr. C. H. Roux of our Anatomy Department. In the following pages the extracts quoted have been taken from this translation.

1. *P. laticolumnatus* (fig. 6, A).

Van Hoepen (1932) discovered four fragmentary loose teeth, a piece of snout with a left upper third molar *in situ* and a skull with damaged

A B C

FIG. 6.—Occlusal view of third molars of *P. laticolumnatus* (A), *Stylochoerus compactus* (B), and *Synaptochoerus hieroglyphicus* (C). (After Van Hoepen.)

molars. After investigation, he concluded that this material represented a new species of wart hog which he named *Phacochoerus laticolumnatus*. The tooth in the snout, which he accepted as the type of the species, has the following characters:—

| | |
|---|---|
| Height (at anterior end) | 58 mm. |
| Height (at posterior end) | 37 mm. |
| Mesio-distal length of concave occlusal surface | 72 mm. |

It has "six pairs of side cones, the front pair of which are fused in one mass, and only three small cement islets remain." Other cones also exhibit fusion and many of the side cones "have long narrow figures which are broad anteriorly and pointed posteriorly." Originally, there was a simple posterior cone, but the greater portion was broken away when the specimen was discovered. "All the cones of the middle row and the

posterior cone have fused into a narrow irregular plate." A lateral view shows "broad flat cones." "Between the main cones are small conules about the diameter of matches, which reach half the height of the tooth between the third and fourth side cones, but between the last three cones they nearly reach the masticatory surface. The conules are apparently fused with the large cones and they will appear on the masticatory surface as extra folds. The outer cones show an ill-defined, weak, vertical, wrinkled surface. The inner cones are also vertically wrinkled, but give a smoother impression." A "complex" is present on the first pair of cones, which are short and terminate in very short roots. The number of roots is uncertain "as the tooth is still in its alveolus." The second pair of cones are well worn and have root platelets (wortellappe). The root ends of the remaining cones are still open. The specimen is not fossilized.

From Van Hoepen's description and illustrations the present writer is unable to see any reason for concluding that this tooth represents a new species of *Phacochoerus*. It is true it presents a combination of uncommon characters, but at the same time it has no characters which are not also met with in the third molars of the modern wart hog *P. africanus*. Its dimensions are similar to those of the lower molars in skull 5829 from Albany Museum. The degree of fusion of its columns and the presence of only cement islets at the anterior end are characters which are also met with in modern wart hog third molars. The concave occlusal surface is the result of mal-occlusion between this tooth and its corresponding lower third molar. Due to this mal-occlusion the ends of the columns on the occlusal surface were abraded at an angle, and this gave rise to islands which have "long, narrow figures which are broad anteriorly and pointed posteriorly." Fig. 7 is a lateral view of a specimen in the writer's collection which presents a concave occlusal surface and which in addition presents islands which have the same form as those in Van Hoepen's *P. laticolumnatus*.

Possibly, however, it is the presence of small "conules" on the outer surface of the main columns which led Van Hoepen to believe that the specimen represented a new species. It has been shown in this report that similar conules are found on the teeth of modern wart hogs. They have been compared by the writer with Bolk's "paramolars," and are present not only in some of the modern third molars but also on some of the loose, fossilized third molars previously described. They are merely anomalies. The presence of wrinkled enamel on some of the columns of *P. laticolumnatus* is likewise unremarkable and, except that the specimen belongs to an older animal, is ill-formed as a result of mal-occlusion, and presents the anomaly of possessing conules, it appears to have no characters which distinguish it from the *P. africanus* tooth illustrated by G in figs. 1 and 2. Since the

other specimens which Van Hoepen includes in this new species have also no characters which specifically distinguish them from third molars of

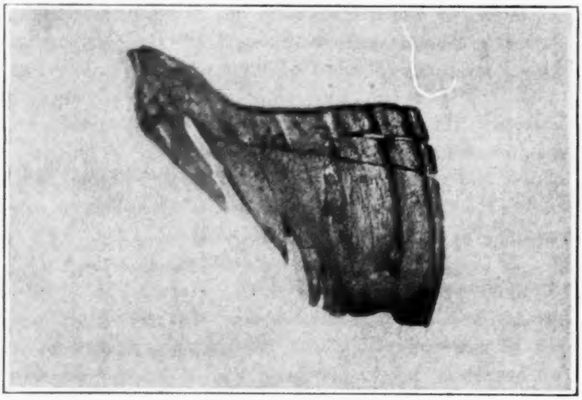

FIG. 7.—Third molar of *P. africanus*, showing concave occlusal surface. (*Vide* Van Hoepen's description of the third molar of *P. laticolumnatus*.)

modern wart hogs and since, moreover, none of the specimens are even fossilized, it seems unwarranted to consider that they represent a new species of wart hog. It is concluded, therefore, that *P. laticolumnatus* is a synonym of either *P. africanus* or *P. aethiopicus*—probably the latter.

2. *Stylochoerus* n.g. *S. compactus* n. sp. (Van Hoepen). (Fig. 6, B.)

The tooth representing the type of this species and genus is a non-fossilized right upper third molar. The description of the characters which distinguish the genus is exceedingly vague. It reads as follows: "M 3 high. Enamel thin. Many cones with a flat portion near the mid-line of the tooth, which in the masticatory surface is connected with the outer part by a narrow bridge."

This right upper third molar measures 76 mm. in height, 49 mm. in length, and 15 mm. in width. It is, therefore, remarkable on account of its great height. Actually, this fact is not stressed in Van Hoepen's report, and it appears that only the characters presented by the columns on their abraded, occlusal surfaces suggested to Van Hoepen that the tooth represents a new genus. There are six pairs of marginal columns and a single distal column. According to Van Hoepen (1932) "between the second pair of side cones is a cone which apparently must be regarded as the first cone of the middle row. Its posterior end is fused with the middle of the

side wall of the second left side cone. The first middle cone thus appears as an enlarged projection of the second cone. Thereafter, however, follow two rows of middle cones each comprising six cones. These cones stand regularly in pairs. The anterior cone complex is formed only by the first two side cones." A detailed description of the form of this complex is then provided, after which the remaining side cones are described. The first right side cone is stated to be "nearly divided into two parts by an outer and posterior inlet. The inner portion is shorter than the outer." The third right side cone has "a large projection antero-medially." The third left side cone "also has a large projection antero-medially. The cones of the fourth pair are nearly similar; they have a small projection antero-medially and a concave anterior wall." The fifth and sixth right side cones "are very narrow. Those of the right side have a sharp angle antero-medially."

In the writer's opinion this description of the occlusal islands is misleading. It is quite evident that the tooth presents the anomaly of two rows of median columns. In other words it is a tooth of the type illustrated in fig. 3 (*a*) 1, (*b*) 1, and (*c*) 1. Whereas, however, the teeth in this figure are only slightly abraded and have two rows of median columns in only certain positions, in Van Hoepen's specimen attrition is marked and two rows of columns are present throughout almost the entire length of the tooth. The sections (*a*) 2, (*b*) 2, and (*c*) 2 illustrated in fig. 3 fully confirm this view, and consequently a correct description of the *Stylochoerus* upper third molar would read as follows:—

There are six pairs of side cones, a single posterior cone, a single anterior cone, nine median buccal and nine median lingual cones. The anterior cone, the first pair of side cones and the first pair of median cones have united to form the "anterior complex." The second right side cone is fused with the second right median cone and the second left side cone is fused with the second left median cone. The third left median cone is separate, but the third right median and side cones are united. The remaining median and side cones are also separate. Between the third and fourth left side cones there is a small cone which may belong to the median series (Van Hoepen's illustration is incomplete at this situation). It is probable, therefore, that at this situation there are three rows of median cones. Union of the marginal and median columns on the anterior half of the tooth has taken place in such a way as to give the appearance that median columns are absent and that the marginals possess complex shaped prolongations.

There is no doubt that this is the correct interpretation of the characters exhibited by this tooth, and in fact at the end of his description of the columns, Van Hoepen (1932) remarks that "the general appearance of the

masticatory surface is as if four rows of cone elements were present; two outer rows which correspond with the ordinary rows which we already know in *Phacochoerus* and two inner rows which at the anterior end are fused as flanges to the inner side of the outer rows and posteriorly function as free cones." Apparently, however, Van Hoepen was not aware that teeth with four series of columns are found in *Phacochoerus* and consequently he felt justified in concluding that teeth with this number of columns represented a new genus.

The remainder of Van Hoepen's description of this tooth deals with the condition of the roots. No reference is made to the other characters which are supposed to distinguish the genus, namely, the "thin enamel" and the "flat portion near the mid-line of the tooth which on the masticatory surface is connected with the outer part by a narrow bridge," and, in fact, as translated this statement has no meaning. Nevertheless, it is quite clear that the tooth has no characters which warrant the assumption that it represents a new genus. On the contrary, although it is slightly taller than any of the specimens in the writer's collection, it obviously belongs to either *P. africanus* or *P. aethiopicus*. That is to say, *Stylochoerus* is a synonym of *Phacochoerus*, and *S. compactus* is either *P. aethiopicus* or *P. africanus*.

3. *Synaptochoerus* n.g. *S. hieroglyphicus* n. sp. (Van Hoepen). (Fig. 6, C.)

In concluding his description of the *Stylochoerus* teeth, Van Hoepen states:—

> "The teeth of *Stylochoerus*, which are described here, all belong to the upper jaw—at least it is assumed that this is so. We have not discovered lower molars conforming to this model. We have, however, found four lower molars which have certain characters in common with *Stylochoerus*. For example, most of the side cones have a large medial projection. The second pair of side cones have transverse projections which unite with one another in the mid-line and interrupt the middle row. There are also, however, important differences. For example, two cones of the middle row are separated from the rest by the second pair of side cones, while in *Stylochoerus* only one cone gets cut in this manner. The H-shaped cones of *Stylochoerus* are not present here, while here also a double row of cones on the middle row is not seen. Further, the first pair of side cones do not broaden on one another as a pair of flanges; in short, where the upper molars of *Stylochoerus* are built up of four rows of tooth elements these lower molars have only three such rows."

These four lower molars provide the evidence for the establishment of

the genus *Synaptochoerus*. The occlusal surface of the type specimen is illustrated in fig. 6, C, but as the above quotation provides a clear understanding of the characters which Van Hoepen considers warrant the establishment of the genus, no useful purpose would be served by describing this type specimen in detail. It is clear that the presence of three instead of four rows of columns made Van Hoepen separate *Synaptochoerus* from *Stylochoerus*, while the form of the islands of these three rows induced him to distinguish *Synaptochoerus* from *Phacochoerus*.

In the writer's opinion Van Hoepen again interprets the significance of the characters incorrectly.

It appears that he has failed to recognise that teeth which present four rows of simple columns when attrition is slight, present three rows of complex-shaped columns when attrition reaches a stage where it exposes the union of columns. The *Synaptochoerus* teeth have no characters which warrant their separation from the *P. africanus* teeth illustrated in fig. 3. The antero-medial projections are of the same type as those seen in the marginal columns of sections (*a*) 2, (*b*) 2 and (*c*) 2 (fig. 3). The transverse projections resemble the transverse projection seen at the mesial end of the section (*c*) 2. Moreover, the transverse projections in this section separate the cones of the middle row just as they do in the *Synaptochoerus* teeth. The projection on the marginal columns of these sections were originally median columns and comparison of the sections with the *Stylochoerus* teeth leaves no doubt that the projections on the latter also represent median columns. The slight differences in the actual form and number of the projections in the writer's sections and in Van Hoepen's teeth may be explained by the fact, previously discussed, that the form, number and arrangement of the columns varies markedly in different teeth. Moreover, it is unreasonable to expect that sections through partially developed and slightly abraded teeth, *i.e.* the writer's specimens, would present characters identical to those exhibited by teeth which are more fully developed and severely abraded. The apparent differences are, in fact, only differences in the degree of development of similar characters. In view of this it must be concluded that *Synaptochoerus*, like *Stylochoerus*, is a synonym of *Phacochoerus*.

4. *Tapinochoerus* n.g. *T. modestus* n. sp. (Van Hoepen).

According to Van Hoepen (1932) the type of this genus and species is a pair of upper third molars probably belonging to the same animal. On both teeth the anterior pair of side cones originally had roots, but these were missing when the specimen was discovered. "The height of the right tooth, measured at the first pair of side cones to where the roots are

broken off, is 40 mm. The third pair of side cones is now the highest and measures from the tip to the free edge of the root plates 53 mm. The breadth of the masticatory surface is 14·5 mm. and the greatest length of the tooth 62 mm. There are five pairs of side cones." The remainder of Van Hoepen's description of these teeth deals mainly with the form of the columns, but it is stated that in one of these specimens there are only six median columns. Special significance is given to the fact "that before half of the columns reach the masticatory surface, roots are present at the anterior extremity and the bases of all the columns are closed."

A third lower molar of *Tapinochoerus* is also described. Van Hoepen then states that "to this genus also belongs the tooth described by Broom as *Notochoerus meadowsi*. Seen from the side this tooth exhibits five pairs of side cones, not six, as stated by Broom."

Through the courtesy of Dr. Broom, the present writer had the opportunity of inspecting the *N. meadowsi* tooth and found that Van Hoepen was incorrect in saying that the specimen has only five pairs of side cones. However, even if only this number were present, the variation in the number of columns in individual extinct and modern pigs would render this fact a matter of no significance. In a right lower molar of *N. meadowsi* described by the writer there are seven pairs of marginal and twelve median columns; in a left lower molar of the same species (and probably of the same animal) there are six pairs of marginals and eleven median columns, while in an upper molar there are six pairs of marginals, ten medians and four "extra" columns. Moreover, in two *N. meadowsi* lower molars and one upper molar recently discovered by Dr. Broom and the writer respectively, there are yet other variations in the number of columns. While, however, the number of columns is unimportant, the writer agrees with Van Hoepen that the *Tapinochoerus* teeth and Broom's *N. meadowsi* tooth closely resemble one another and must be considered to represent the same genus. In fact, since the teeth of the former are younger than the *N. meadowsi* tooth and it has been demonstrated that teeth of the wart hog type vary considerably in form and size during growth, it is probable that the *Tapinochoerus* teeth and Broom's *N. meadowsi* tooth represent the same species. For reasons which will be referred to later in this Report, it is considered, however, that the three *Tapinochoerus* teeth are upper third molars, and that Broom correctly identified the original *N. meadowsi* tooth as a lower third molar. It is, therefore, only necessary to inquire into Van Hoepen's reasons for changing the genus name from *Notochoerus* to *Tapinochoerus*. The only reason given by this investigator is that "*Tapinochoerus* differs from *Notochoerus* in its greater number of cones in the middle row and its less folded phacochoerus-like side cones."

It is true that the number of cones in the middle row is more numerous

in the *Tapinochoerus* and *N. meadowsi* teeth than in the tooth of Broom's *Notochoerus capensis*. In the writer's opinion this difference is due to the fact that the *N. capensis* tooth is severely abraded and belongs to an old animal. The present Report has shown that in young third molars of modern wart hogs, the columns are more numerous and have a simpler form than in older teeth in which union of the columns has occurred. A previous Report (Shaw, 1938) demonstrated that a similar state of affairs presents itself in young and old third molars of extinct pigs. It showed in fact that in all probability the *N. meadowsi* third molars are young third molars of Broom's *N. capensis* and that further development and abrasion of the former would have disclosed a smaller number of columns. Inversely, this Report provided evidence that at an earlier stage of development and wear the *N. capensis* tooth had a larger number of columns than are now present.

There is no good reason for substituting the name *Tapinochoerus* for *Notochoerus*, and in fact since the latter is the older name it must be retained. On the other hand there is evidence to show that Broom's *Notochoerus meadowsi* and Van Hoepen's *Tapinochoerus modestus* are synonyms of *N. capensis*.

5. *Kolpochoerus* n.g. *K. sinuosus* n. sp. (Van Hoepen). (Fig. 8, A.)

For an understanding of the characters presented by the third molars of this genus and species, it is sufficient to provide their principal dimensions and Van Hoepen's account of the characters which distinguish them from the third molars of *Notochoerus capensis* of Broom (1925). The following are the dimensions of the left upper third molar which was taken as the type:—

| | |
|---|---|
| Length of masticatory surface | 63 mm. |
| Greatest width (over second pair of cones) | 25 mm. |
| Height of crown (anteriorly) | 11 mm. |
| Height of crown (posteriorly) | 28 mm. |

The dimensions of two fragmentary teeth which "are apparently lower molars" are as follows:—

*Specimen C.* 799.

| | |
|---|---|
| Length of masticatory surface as preserved | 41·0 mm. |
| Width (anteriorly) | 21·5 mm. |
| Width (posteriorly) | 17·5 mm. |
| Height (anteriorly) | 18·0 mm. |
| Height (posteriorly) | 25.5 mm. |

*Specimen C. 800.*

| | |
|---|---|
| Length of masticatory surface as preserved | 41·0 mm. |
| Width (anteriorly) | 20·5 mm. |
| Width (posteriorly) | 16·5 mm. |
| Height (anteriorly) | 4·0 mm. |
| Height (posteriorly) | 15·0 mm. |

As will be seen the three specimens reported on differ in their dimensions. It appears, however, that the short mesio-distal length of the masticatory surfaces in the specimens C. 799 and C. 800 is due to the loss of the posterior

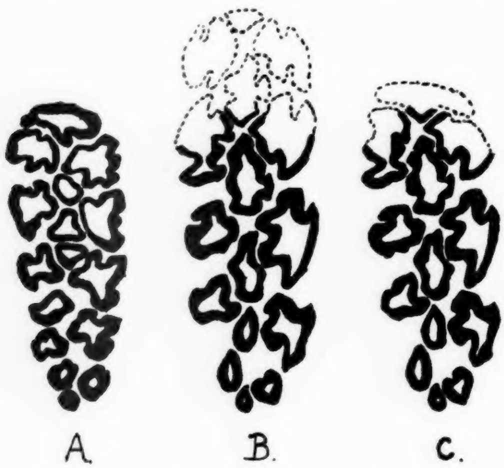



FIG. 8.—Upper third molars of *Kolpochoerus sinuosus* (after Van Hoepen), A; upper third molar of *N. capensis* (as reconstructed by Broom), B; upper third molar of *N. capensis* (as reconstructed by Shaw), C. All approximately natural size. Occlusal view.

and anterior extremities respectively, while the differences in the height of the three specimens is possibly explained by differences in the degree to which they have been affected by attrition.

According to Van Hoepen, "*Kolpochoerus* differs from *Notochoerus* by its small size, the concave outer wall of its outer cones, the division into three of the outer walls of its first outer side cone, its two cones of the middle row between the second and third pairs, the lessened slant of the base of its crown in relation to the masticatory surface and by the fact that the molars rapidly become narrower posteriorly. In *Notochoerus* the sides of the molar run nearly parallel." The writer considers that none of

these characters, except perhaps the small size, are of sufficient importance to warrant separating *Kolpochoerus* from *Notochoerus*. Throughout his Report (1932) Van Hoepen attaches great importance to the form and arrangement of columns, but this investigator was not aware that even in modern wart hogs these structures vary exceedingly in their characters in different individuals. In the *N. capensis* (Syn. *N. meadowsi*) teeth reported on by the writer, variation in the characters of the columns is also of frequent occurrence and the assumption is therefore warranted that in *Kolpochoerus* the form of the walls of the columns, the division of the columns and the number of median columns are characters of only individual significance. Differences in the age of the specimens entirely account for the different "slant" of the bases of the *Kolpochoerus* and *Notochoerus capensis* teeth, and it is incorrect to say that in *Notochoerus* the side walls run nearly parallel. Near its anterior extremity the *N. capensis* tooth has a width of approximately 30 mm., but at the distal columns (midway between the base and occlusal surface) the width is only 19 mm. At the second pair of columns from the distal end the width is only 25 mm. If these measurements are taken at the occlusal surface, the widths are 12 and 19 mm. respectively. In other words both the *N. capensis* and *Kolpochoerus* third molars narrow perceptibly towards the posterior end. There is no doubt, however, that the *Kolpochoerus* third molars are distinctly smaller than the *N. capensis* tooth as reconstructed by Broom (1925). Although the present writer accepted this reconstruction in his previous Report (Shaw, 1938), re-examination of the original specimen and comparison of its characters with those exhibited by Van Hoepen's *Kolpochoerus* type specimen, seem to indicate that this reconstruction is incorrect.

Fig. 8, B from Broom's Report is a natural size illustration of the *N. capensis* tooth restored to what Broom (and later the writer) believed to be its original condition. It will be seen that the reconstructed portion of the tooth contains an additional pair of marginal columns, an additional median column and extensive prolongations to the existing damaged median and marginal columns.

Although the specimen, as preserved, measures only 64 mm., the length of the tooth, as reconstructed by Broom, is 79 mm. Fig. 8, C shows the writer's reconstruction of the *N. capensis* tooth. Only small extensions are added to the damaged pair of marginal columns, and Broom's first and second median and first pair of marginal columns are replaced by a single median column like that seen at the anterior extremity of the *Kolpochoerus* type specimen. This reconstruction considerably reduces the size of the tooth, making it only slightly larger than the *Kolpochoerus* tooth (fig. 8, A).

If this is correct, the original length of the *N. capensis* tooth was approximately 66 mm., compared to a length of 63 mm. in the *Kolpochoerus* type specimen. Neither this difference nor the slight difference in the width of the *N. capensis* and *Kolpochoerus* specimens are of sufficient importance to warrant the view that these teeth represent different genera. Possibly, they represent different species, but since it has been demonstrated in the present Report and in Van Hoepen's illustrations that one of the most conspicuous characters of teeth of this type is their tendency to present individual variations, the writer feels that this is not the case. On the contrary, since there is evidence in support of the view that even *N. meadowsi* and *Tapinochoerus modestus* are synonyms of *N. capensis*, it is more reasonable to assume that the latter is the only genus and species of its kind so far satisfactorily identified. It is concluded, therefore, that *Kolpochoerus* is a synonym of *Notochoerus*, and that *Kolpochoerus sinuosus* is *N. capensis*.

6. *N. capensis* syn. *N. meadowsi*.

Reference has been made to the writer's Report (Shaw, 1938) on the third molars of *N. capensis* and *N. meadowsi*, and to his conclusion that *N. meadowsi* is a synonyn of *N. capensis*. The present investigation has provided no evidence which requires the alteration of this conclusion. On the contrary, it is believed it provides additional evidence that *N. capensis* is the only extinct giant pig so far identified in South Africa. If, however, the writer is correct in concluding that the *Kolpochoerus* and *N. capensis* teeth represent the same genus and species, both he and Dr. Broom have in the past accepted a wrong reconstruction of some of the missing portions of the *N. capensis* and "*N. meadowsi*" teeth previously discovered. Moreover, the present writer erred in his interpretation of the significance of some of the characters presented by these teeth.

The *Kolpochoerus* teeth show that Broom's reconstruction of the anterior end of the *N. capensis* tooth is probably incorrect. The discovery of the *N. capensis* tooth was the first indication of the former existence of a giant pig of the wart hog type. Evidence was therefore entirely lacking concerning the manner in which the missing anterior portion of this tooth should be reconstructed. Broom was, therefore, faced with the alternative either of failing to provide a reconstruction or providing a reconstruction which was entirely hypothetical. He adopted the latter alternative. Now, however, when additional teeth of a giant pig (*Kolpochoerus*) have been discovered it is obviously preferable that Broom's reconstruction should be superseded by a reconstruction which conforms with a known type of tooth. This has lead to the conclusion that the mesio-distal length

of the *N. capensis* third molar is approximately 66 mm. and not 79 mm. as in Broom's reconstruction.

Dr. Broom and the present writer were probably also incorrect in their view that anterior roots of the type found in modern wart hogs were developed in the *N. capensis* tooth. The *Kolpochoerus* teeth show that while the columns close at their bases, as they do in modern wart hogs, closure of the anterior group of columns fails to result in the development of regularly formed anterior roots. In view of this, there is reason to believe that such roots were also lacking in the *N. capensis* tooth. This conclusion renders it improbable that the anterior group of columns in this tooth were entirely worn away by attrition. Apparently, although severely worn, these columns were retained during the life of the animal.

The writer's conclusion (Shaw, 1938) concerning the original form of a damaged "*N. meadowsi*" upper third molar also appear to have been incorrect. The mesio-distal measurements of two "*N. meadowsi*" third molars discovered at Sterkfontein by the writer are 77 mm. and 79 mm. respectively, while the original *N. meadowsi* third molar discovered by Broom (1928) has a length of 76 mm. The corresponding length of Broom's reconstruction of the *N. capensis* third molar is 79 mm. As in addition the general characters of the four teeth are fundamentally similar, the writer concluded that they belong to the same species (*N. capensis*), but that the "*N. meadowsi*" teeth are from the lower jaws of young animals while the original *N. capensis* tooth belongs to the upper jaw of an old animal.

At the writer's disposal there was also a young "*N. meadowsi*" upper third molar (fig. 9). For reasons which were stated in the previous Report, this tooth was identified as belonging to the same animal as that represented by the two young lower molars discovered at Sterkfontein. This young upper molar, however, is damaged at its distal end, and while evidence was lacking concerning the size of the absent portion, it seemed possible that it was large and that prior to damage the tooth had approximately the same mesio-distal length as the lower molars, *i.e.* 76–79 mm. In addition it was concluded that with further development and wear this tooth also would have come to resemble Broom's reconstructed *N. capensis* upper third molar tooth.

Recently the writer has had the good fortune to discover another young "*N. meadowsi*" upper third molar (fig. 9). This tooth is also damaged, but the missing portion is at the anterior end. The distal end is well preserved and shows that, contrary to the writer's earlier belief, the original young "*N. meadowsi*" upper third molar lacks at its distal end only one or two small columns. Consequently, its maximum mesio-distal length could not have exceeded 66 mm. It is therefore not only smaller than the

corresponding molars from the same lower jaw, but is also smaller than the *N. capensis* upper molar as reconstructed by Broom (1925).

If, therefore, Broom's reconstruction is correct, the two young upper molars in the writer's collection cannot be identified as *N. capensis* teeth. On the other hand if the writer's reconstruction of the *N. capensis* tooth is correct, it is evident that the solution of the problem lies in the fact that in *N. capensis* there is a marked difference in the mesio-distal length of upper and lower molars. From the evidence now available it appears that upper molars are markedly shorter than lower molars. Broom's aged *N. capensis* tooth and Van Hoepen's aged *Kolpochoerus* type specimens are upper third molars, and if the former is reconstructed in the manner suggested by the writer these two specimens have approximately the same mesio-distal length, *i.e.* 63 mm.–66 mm. The length of the young "*N. meadowsi*" upper third molars discovered by the writer and of Van Hoepen's *Tapinochoerus* teeth is also 63 mm.–66 mm., but on the other hand, with the exception of two very young lower third molars recently discovered by Broom, "*N. Meadowsi*" lower third molars measure 76–79 mm. mesio-distally. The two lower third molars recently discovered by Broom have not yet been reported on, but through the courtesy of Dr. Broom the writer has been able to examine them. They measure only 65 mm. mesio-distally at their base, but as only the tip of their first pair of columns is abraded it is evident that they are considerably younger than any of the teeth of this type previously discovered. It is also evident that with further development they would have become markedly larger mesio-distally. They therefore support the writer's view that in this species lower molars are larger mesio-distally than upper molars. They also show, however, that this difference only exists between upper and lower third molars of corresponding age. This is only what might be expected, for, as has already been shown when dealing with the teeth of modern wart hogs, even young and old teeth from corresponding jaws normally vary markedly in their characters. If, however, allowance is made for age variations, the evidence now available warrants the conclusion that the following are the principal characters of the third molars of *N. capensis* syn. *meadowsi*:—

(*a*) Upper Molars.

| | |
|---|---|
| Maximum mesio-distal length . | Approximately 63 mm.–66 mm. |
| Maximum labio-lingual width at occlusal surface . . | Approximately 25 mm.–30 mm. |

*Note.*—In young upper third molars the occlusal surface measures only 20 mm., but at the base a width of 30 mm. is attained (*vide* Shaw, 1938).

| | |
|---|---|
| Anterior roots . . . | Absent. |
| Closure of columns . . | Occurs early. |


FIG. 9.—The "*N. meadowsi*" upper third molars: (*a*) the original specimen; (*b*) the second specimen discovered.

(*b*) Lower Molars.

| | |
|---|---|
| Maximum mesio-distal length . | Approximately 76 mm.–79 mm. |
| Maximum labio-lingual width at occlusal surface . . . | Approximately 20 mm. |
| Maximum labio-lingual width at base . . . . . | Approximately 20 mm. |
| Anterior roots . . . . | Absent. |
| Closure of columns . . . | Occurs early. |

In both upper and lower molars the height of the teeth and the number and form of the columns vary in different animals and at different stages of growth and attrition.

## Summary and Conclusion.

Previous Reports dealing with pigs of the wart hog type may be divided into reports of two types. The first describes new genera and species of pigs, and the second contends that there is insufficient evidence for the establishment of these new genera and species. Although the present Report belongs to the latter category it is believed that the subject has been approached in an entirely new manner.

As many extinct genera and species of pigs have been identified from the characters of third molar teeth, the primary object of the investigation was to discover the result of growth and wear changes in the third molars of modern wart hogs and the significance of such changes in relation to characters identified on fossilized and semi-fossilized wart hog third molars. First, however, it was necessary to determine the species represented by a number of modern skulls in the writer's possession. For this purpose the measurements and relative proportions were secured. Unfortunately, it was found that contrary to the view expressed by Lönnberg (1908) skull proportions fail to distinguish *P. africanus* from the recently extinct *P. aethiopicus*. It was, in fact, found that skull proportions in the wart hog are too inconsistent and unreliable for systematic purposes. Nevertheless, it was shown that in all probability the collection of skulls represent the species *P. africanus*.

A short account of the incisor teeth in this species is followed by a full description of variations in the third molars due to growth, attrition and other factors. It is demonstrated that the detailed anatomical characters of modern third molars vary in a manner not previously suspected. Many of these variations are largely the result of growth and wear, but it is shown that in addition there are several important variations which are predetermined and not acquired. Investigation of these subjects warrants the conclusion that a type for wart hog third molars does not exist.

As Van Hoepen (1932) reported on differences between the third molars of *P. aethiopicus* and *P. africanus* an attempt was made to secure further information on this subject. Van Hoepen's view is confirmed, namely, that in the former, root development on the third molars occurs at a later stage than in *P. africanus*. The number of *P. aethiopicus* teeth available was insufficient to allow detailed investigation of growth and wear changes in the third molars of this species, but it is shown that there is evidence for the belief that although roots and other structures develop later in this species than in *P. africanus*, the third molars of both species eventually develop corresponding characters.

The greater part of the remainder of the Report deals with a number of third molars which Van Hoepen considers to represent new genera and species of extinct pigs. It is shown that the evidence now available concerning variations in the third molars of modern wart hogs renders it improbable that these teeth represent different genera or species from those already known. The characters of the third molars of Van Hoepen's *P. laticolumnatus* are briefly described, and it is concluded that these teeth are old specimens of either *P. africanus* or *P. aethiopicus*. The characters of the third molars of Van Hoepen's *Stylochoerus* and *Synaptochoerus* are shown to be identical with characters which occur as abnormal variations in the corresponding teeth of *P. africanus*. These genus names are therefore also synonyms of *Phacochoerus*. The genus *Tapinochoerus* of Van Hoepen has third molars which are markedly larger and differ also in other respects from the third molars of *Phacochoerus*. In fact, Van Hoepen shows that these teeth closely resemble Broom's (1925) *N. meadowsi* tooth. While, however, Van Hoepen believes that the *Tapinochoerus* and *N. meadowsi* teeth have similar characters, he considers that the genus *Tapinochoerus* differs from Broom's *Notochoerus*. The evidence advanced fails to support this view, and it is shown that owing to the demonstrated tendency for variations in the number of columns in teeth of this type, it is preferable to regard *Tapinochoerus* as a synonym of *Notochoerus*.

The characters of Van Hoepen's *Kolochoerus sinuosus* type specimen are described, and it is demonstrated that this species name is also probably a synonym of *Notochoerus capensis*.

Finally, it is shown that in *N. capensis* the upper third molars are markedly smaller than the corresponding lower molars, and that this fact probably explains the difficulty previously experienced in recognizing that *N. meadowsi* is a synonym of *N. capensis*.

In conclusion it may be stated that although the opportunity of examining the third molars of *Metridiochoerus* of Hopwood (1926) has not presented itself, the published descriptions of this tooth have convinced

the writer that Broom (1928) is correct in stating that *Metridiochoerus* and *Notochoerus* are identical. The writer is also in complete agreement with Van Hoepen's conclusion (1932) that the four species of *Phacochoerus* erected by Dreyer and Lyle (1931), namely, *P. helmei*, *P. venteri*, *P. meiringi* and *P. dreyeri* are synonyms of either *P. aethiopicus* or *P. africanus*. It is evident, therefore, that only one living species of wart hog (*P. africanus*), one recently extinct specimen of wart hog (*P. aethiopicus*), and one extinct giant pig (*Notochoerus*) have been satisfactorily identified.

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# POPULATION FLUCTUATION OVER 7000 YEARS IN EGYPT.*

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(With Plate VIII, and one Text-figure.)

(Read September 21, 1938.)

## CONTENTS.



## INTRODUCTION.

The living races of mankind to-day are so mingled that the puzzle of the last century has been how best to separate them. Like different varieties of a single animal species they cross and breed out more or less truly to type. Of these interbreeding racial varieties we can recognize, in terms of our genealogical diagram (see fig. 1):

1. The ellipsoidal (dolicho-hypsicephalic) and leptorrhine Nordic (or European or Caspian) type, whose homeland was Europe west of the Ural mountain range.

2. The square (brachy-hypsicephalic) and leptorrhine Armenoid (or Alpine) type, whose homeland was Asia west of the Gobi desert.

Both of these are white-skinned, hirsute and long bearded, the Armenoid being somewhat more tawny-coloured; both have elevated aquiline noses, but the Armenoid type is more hooked; both have robust frames, the former being long and lank (asthenic), the latter more thick-set and stockish

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(hypersthenic); both are mature or adult types of mankind (gerontomorphic); both are large-headed (macrocephalic), and seem to have given the world most of its adventurous acting and thinking, invention and philosophy, both destructive and constructive.

3. From Morocco to Burma stretches the brown-skinned "Hamitic" group of peoples of the Brown (or Mediterranean) type, whose homeland is placed in north-east Africa. Their obtusely pentagonoid skulls are dolicho-orthocephalic.

4. East of the Gobi desert lie the yellow-skinned Asiatics of the Mongol (or Yellow) race. Their rounded skulls are short and moderately high.

In contrast with the two adult types these are juvenile in their cranial form; their bodies are youthful in type, the former being more elongated (hyposthenic), the latter more thickset (sthenic); both have brains of moderate size (mesocephalic). They are both prolific, active, industrious and peaceful. Being teachable and receptive their central territories absorbed everything culturally and have become the repositories of the history of mankind. Biologically they are dominant types, and are not burdened with a sense of inferiority.

5. Another even more juvenile, and less prolific, active and industrious, but far more light-hearted and happy type of mankind is the Negro type, whose homeland was South of the Sahara perhaps in the Congo area. Flat-nosed, oval-headed and mesocephalic his blackness of skin is more akin to that of

6. The Australian type, whose probably African but very ancient homeland is unknown. Scattered through India and the Eastern Archipelago these still less active folk seem to have lost much of their ancestral fertility. To Africa they are still linked by

7. The Boskop type, which has been considered in previous articles (Dart 1937, *a* and *b*).

These two latter types appear to have been early attempts at gerontomorphism in the sapient stock. But there are two forms of living mankind, which, by retaining truly infantile or paedomorphic characteristics, display the pristine innocence of that stock. Less black than the Negro but not so light-skinned as the Brown or Yellow races are

8. The long-headed Bush (pygmy) stock of Africa and

9. The short-headed Negrito (pygmy) stock of the south-eastern Asiatic islands.

Both of these types have acutely pentagonoid or baby-like types of skulls which are set on child-like frames with tiny hands and feet and surmounted by foetal faces. All these characters reveal them as infants of the sapient human race. With their small (microcephalic) heads and their trustful, infant outlook goes their merry, dancing, care-free life.

They are the children of men, the prototypes of fairies, gnomes and pixies.

Whether this classification of mankind is adequate to account for all the physical phenomena encountered in the world's living population, time alone can tell; it forms an adequate basis from which to proceed in the further analysis of the peoples, with which we are more intimately concerned in South Africa and Egypt, the southern and northern extremities of this vast continent.

A comparative survey of African tribes based on physical data accumulated by anthropologists in the field and in the laboratory led (Dart, 1937 *a*) to two sweeping but basic conclusions: firstly, that hypsicephaly (high-headedness) is alien to all three of the races, the chamaecephalic Bush, and the orthocephalic Negro and Brown races that predominate in the three major transcontinental, anthropological, territorial belts of Africa as we proceed from south to north; and secondly that, despite this original absence, hypsicephaly is now present and has pervaded the entire continent in such a fashion that we encounter it with gradually increasing intensity on proceeding from the south-east to the north-west of the continent.

The potential sources of this immigrant African hypsicephaly are dual: they are the *brachymorphic hypsicephaly of Asia* manifested in the short, high-vaulted heads of the Mongolian and Armenoid peoples and the *dolichomorphic hypsicephaly of Europe*, exhibited by the long-vaulted heads of the Nordic people. The percentage of short- or square-headed individuals in the Bantu fluctuates from tribe to tribe investigated, but is greatest in those of the eastern seaboard; the Comoro Islanders are so square-headed as to resemble the Arabs of Yemen and Aden in Arabia, and the coastal population of Biloch and Cutch in India, more closely in this respect than they resemble their Bantu brethren on the African mainland. The increasing, short-headed hypsicephaly, as we march up the east coast, presented no real difficulty; it was logically explained by the age-long commerce and traffic of the Indian Ocean between Asiatics and African, which is outlined in scattered but actual historical narratives.

This hypsicephalic quest would have terminated there had it not been discovered that the incidence of high-vaults is not coterminous with the distribution of short-heads in Africa. Hypsicephaly occurs independently from brachycephaly, and is profuse where long-heads are most frequent and there is least brachycephaly; namely, amongst the essentially dolichomorphic Western Bantu of the Congo and Angola, and the Negroes of Guinea, Soudan and Senegambia. The only living source of such dolichomorphic hypsicephaly (long-high headedness) known to me was that of the Nordic race, who are characteristic owners of brain-boxes which are simultaneously long and high.

To explain the high percentages of dolichomorphic hypsicephaly found southward of the Soudan, I therefore boldly suggested that, during the more congenial conditions of the last Ice Age in North Africa, the adventurous Nordic people of the Mediterranean littoral had migrated freely over the Sahara and had intermingled in the south with the northerly expanding Negro stock. From the Negro-Nordic admixture in the western Soudanic area there thus emerged the hypsicephalized Negroid stock, which thrust itself across the headwaters of the Nile, inundated the eastern seaboard, and ran like a torrent to the southern extremity of the continent. Consequently to-day some dolichocephalic South African Bantu tribes are as strongly hypsicephalized as the so-called Nilo-Hamites of the Soudan.

If this postulated prehistoric pressure of the Nordic race upon Africa had actually taken place, it would have implications as notable for comprehending the African peoples, their languages, and their history as those attaching to the postulated penetration of the Near and Far East by the same Nordic race in unfolding the Oriental racial and linguistic story. It is so charged with potential implications for African anthropology both physically and culturally, that a failure to exploit any hopeful avenue of approach proffering more precise information on the subject would have been blameworthy.

Apart from the Negro in the west, another great division of the human race occupied the eastern part of northern Africa, viz. the Brown (or Mediterranean) race. So powerful a pressure, as that envisaged could scarcely have been exercised by the Nordic race upon the Negro without some corresponding effect being demonstrable in the territory occupied by the Brown race. I forthwith surveyed the published records available here concerning the ancient Egyptians to see what evidence they might supply corroborating this hypothetical explanation of hypsicephaly in Africa, and incidentally discovered numerous unexpected facts about the population of the Nile Valley down the ages. Thus it emerged that not only had Nordic man at one time overrun Egypt, but also that Bush peoples had played a part in the population minglings of that country.

Now investigations over the past fifty years in Southern Africa have shown that the Bush peoples themselves are not a pure race, but it was not until last year (Dart, 1937 *b*) that, as a result of the investigations carried out in the Kalahari Desert, we were enabled to obtain statistical information to prove that the racial matrix of the Bush races is composed in virtually equivalent parts of two divergent physical types—namely, the Bush (or Pygmy) type, and the Boskop (or "Hottentot" type). It became important therefore to discover whether the Boskop type as well as the Bush type were present in the Egyptian population, and, if so, to what extent.

This paper is therefore an expansion—from the South African point of view—of those valuable inquiries, originated by Thomson and Maciver (1905) and furthered by Morant (1925) and his numerous collaborators in the Galton laboratory, into the sequence of racial changes which occurred in the population of Egypt. Thomson and Maciver insisted that, from the earliest times, the Egyptians were divisible into Negroid and non-Negroid groups. On the other hand, an opinion seems to have been developing that the Egyptians formed a close approximation to that objective, or abstraction of anthropological search—a pure race.

Elliot Smith (1923) demonstrated the persistence of the fundamental, indigenous Brown (or Mediterranean) type in Egypt from the earliest predynastic times (*circa* 5000 B.C.) down to the present day.

Morant (1925), however, went far beyond this standpoint when he said, "As examples of types which were entirely unaffected for several thousand years by any influence foreign to their country, the ancient Egyptians may well be unparalleled in the history of the world." Later he continues, "A study of all the series of early Egyptian crania that have as yet been measured shows that they are interrelated in a simple way. It is most probable that the observed differences between the types are to be explained as being due to some slow-moving evolutionary process —whether through selection or directly through environment—or to a slow blood-mingling of different races. On the latter hypothesis it would only be necessary to assume the existence of two original races, an Upper and a Lower Egyptian, which were distinct in Early Predynastic times."

Morant's simplification of our outlook upon the history of the Egyptians would be attractive if it could be sustained. We owe to him and his fellow-workers an enormous mass of data. But there are biometrical facts—other than constants, means, coefficients and other similar mathematical intricacies—concerning which preliminary cognisance must needs be taken, if we are to reconstruct gradually the unwritten history of mankind. I shall discuss later on a few of these metrical facts in respect to Egyptians culled to a large extent from their (Morant's, etc.) tables, and, by presenting them in a different way, will broach the subject from a very rudimentary but none the less important angle.

## 2. Method and Material.

There are two divergent metrical techniques followed by physical anthropologists which lead to apparently conflicting but in reality complementary results; the one arrives at *average values* in communities, and may be broadly likened to the mathematical process of discovering the lowest common denominator in a given series of numerical quantities; the other aims at *isolating values* that characterize racial types in com-

munities, and may be compared with the procedure of finding the simplest series of numerical quantities, that produce a given common denominator. Both methods afford critical information.

There are of course differences inherent in the two methods—that seeking average or common values is almost wholly metrical in quality; that separating types is metrical, or non-metrical, or a combination of both. Thus Retzius's separation of dolichocephals from brachycephals is metrical, but Sergi's separation of ellipsoids from pentagonoids is non-metrical. Non-metrical features may be assembled and analysed in a metrical fashion (Dart, 1937 *b*). A combination of both methods will assist our present inquiry.

The simple procedure followed by Retzius (1842) of relying upon the *cephalic index* or length-breadth relationship of European skulls to separate the dolichocephals, or long-heads of Europe from the co-existing brachycephals, or short heads (which have thereby been traced to their Asiatic homeland), has had the cardinal importance in anthropology that attaches to a postulate in algebraic science. No lesser selective significance attaches in my estimation to the *altitudinal index* or length-height relationship of skulls, and it is a misfortune that hitherto the racially diagnostic value of the altitudinal index has been overlooked. The genius and simultaneously the limitation of Retzius's unique classificatory mechanism is that it classifies the skull with the aid of two dimensions only. If we cross-classify the triple grouping of short, intermediate and long heads obtained by his method in terms of the altitudinal index, we are able to subdivide each of these three groups into three further sub-groups of high, intermediate, and low skulls; thus, in all, obtaining nine sub-groups. Thereby we arrive metrically at the simplest possible three-dimensional picture of the various types of cranial boxes present in different human groups. For our purpose here, that slightly more involved but still elementary classification is an adequate preliminary; it has the added advantage that the conclusions drawn are readily intelligible to the layman. I have therefore contented myself with classifying in this ordinary fashion all the Egyptian skulls recorded (see Table I), and with setting out the cumulative information in the form of a rough time chart (*vide* Plate VIII), and a bare table of totals (see Table II).*

One of the principal sources of the metrical information used is the meticulous study by Thomson and Maciver (1905) "of the inhabitants of Upper Egypt from the earliest prehistoric times to the Mohammedan conquest based upon the examination of 1500 crania." Of these 1453 were sufficiently "complete" to demonstrate both the cephalic and alti-

* The method resembles that of sorting oranges by passing them over grids of different forms, and I term such a cross-classifying table as this "an anthropological grid."

TABLE I.

*Cross Analyses of Eighteen Samples of "Complete" Egyptian Skulls of different Periods ranging from the Earliest Predynastic to Modern Times to show the Percentage Distribution of Length-width and Length-height Indicial Characteristics in each Group.*

| | DERRY. Badari and Mostagedda. | | | | | FOUQUET. El Amrah, etc. | | | | | FAWCETT and LEE. Nagada. | | | | | THOMSON and MACIVER. Early Predynastic. | | | | | THOMSON and MACIVER. Late Predynastic. | | | | | MOTLEY. Dynasty 1. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % |
| Dolicho | 20 | 31 | 2 | 56 | **70·9** | 17 | 45 | 13 | 75 | **74·3** | 48 | 133 | 31 | 212 | **67·5** | 13 | 44 | 9 | 66 | **74·1** | 17 | 116 | 36 | 169 | **73·1** | 3 | 12 | 9 | 24 | **54·5** |
| Mesatic | 7 | 15 | 1 | 23 | **29·1** | 8 | 15 | 3 | 25 | **24·7** | 39 | 50 | 7 | 96 | **30·6** | 8 | 12 | 2 | 22 | **24·7** | 10 | 38 | 11 | 59 | **25·6** | 1 | 16 | 3 | 20 | **45·5** |
| Brachy | 0 | 0 | 0 | 0 | **0·0** | 1 | 0 | 0 | 1 | **1·0** | 4 | 2 | 0 | 6 | **1·9** | 0 | 1 | 0 | 1 | **1·2** | 2 | 1 | 0 | 3 | **1·3** | 0 | 0 | 0 | 0 | **0·0** |
| Total | 27 | 49 | 3 | 79 | .. | 25 | 60 | 16 | 101 | .. | 91 | 185 | 38 | 314 | .. | 21 | 57 | 11 | 89 | .. | 29 | 155 | 47 | 231 | .. | 4 | 28 | 12 | 44 | .. |
| **Per cent.** | **34·2** | **62·0** | **3·8** | .. | **100·0** | **24·7** | **59·5** | **15·8** | .. | **100·0** | **29·0** | **58·9** | **12·1** | .. | **100·0** | **23·6** | **64·0** | **12·4** | .. | **100·0** | **12·6** | **67·1** | **20·3** | .. | **100·0** | **9·1** | **63·6** | **27·3** | .. | **100·0** |

| | THOMSON and MACIVER. Dynasties 1–5. | | | | | THOMSON and MACIVER. Dynasties 6–12. | | | | | WOO. Dynasty 9. | | | | | COLLETT. Dynasties 12–13. | | | | | THOMSON and MACIVER. Dynasties 12–15. | | | | | SCHMIDT. Dynasty 18 (Abydos.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % |
| Dolicho | 23 | 69 | 27 | 119 | **60·4** | 49 | 124 | 26 | 199 | **63·8** | 6 | 14 | 1 | 21 | **30·4** | 15 | 80 | 27 | 122 | **68·9** | 13 | 68 | 18 | 99 | **64·7** | 2 | 12 | 6 | 20 | **30·3** |
| Mesatic | 19 | 39 | 8 | 66 | **33·5** | 48 | 48 | 3 | 99 | **31·7** | 21 | 19 | 0 | 40 | **58·0** | 17 | 32 | 3 | 52 | **29·4** | 11 | 33 | 5 | 49 | **32·0** | 3 | 31 | 7 | 41 | **62·1** |
| Brachy | 6 | 6 | 0 | 12 | **6·1** | 11 | 2 | 1 | 14 | **4·5** | 8 | 0 | 0 | 8 | **11·6** | 2 | 1 | 0 | 3 | **1·7** | 2 | 3 | 0 | 5 | **3·3** | 2 | 3 | 0 | 5 | **7·6** |
| Total | 48 | 114 | 35 | 197 | .. | 108 | 174 | 30 | 312 | .. | 35 | 33 | 1 | 69 | .. | 34 | 113 | 30 | 177 | .. | 26 | 104 | 23 | 153 | .. | 7 | 46 | 13 | 66 | .. |
| **Per cent.** | **24·4** | **57·8** | **17·8** | .. | **100·0** | **34·6** | **55·8** | **9·6** | .. | **100·0** | **50·7** | **47·8** | **1·5** | .. | **100·0** | **19·2** | **63·9** | **16·9** | .. | **100·0** | **17·0** | **68·0** | **15·0** | .. | **100·0** | **10·6** | **69·7** | **19·7** | .. | **100·0** |

| | THOMSON and MACIVER. Dynasty 18. | | | | | OETTEKING. Dynasty 18 (Probably). | | | | | SCHMIDT. Dynasties 18–21. | | | | | THOMSON and MACIVER. Dynasty 30 and Ptolm. | | | | | THOMSON and MACIVER. Roman. | | | | | SCHMIDT. Modern. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % | H. | O. | C. | Total. | % |
| Dolicho | 9 | 83 | 28 | 120 | **58·8** | 10 | 46 | 19 | 75 | **44·9** | 10 | 60 | 41 | 111 | **44·4** | 9 | 63 | 33 | 105 | **62·5** | 5 | 32 | 15 | 52 | **52·5** | 11 | 11 | 36 | 58 | **41·1** |
| Mesatic | 15 | 52 | 9 | 77 | **37·8** | 14 | 53 | 13 | 80 | **47·9** | 26 | 67 | 17 | 110 | **44·0** | 9 | 36 | 8 | 53 | **31·5** | 7 | 21 | 9 | 37 | **37·4** | 24 | 21 | 4 | 49 | **34·8** |
| Brachy | 5 | 2 | 0 | 7 | **3·4** | 7 | 3 | 2 | 12 | **7·2** | 17 | 12 | 0 | 29 | **11·6** | 2 | 7 | 1 | 10 | **6·0** | 2 | 7 | 1 | 10 | **10·1** | 30 | 4 | 0 | 34 | **24·1** |
| Total | 30 | 137 | 37 | 204 | .. | 31 | 102 | 34 | 167 | .. | 53 | 139 | 58 | 250 | .. | 20 | 106 | 42 | 168 | .. | 14 | 60 | 25 | 99 | .. | 65 | 61 | 15 | 141 | .. |
| **Per cent.** | **14·7** | **67·2** | **18·1** | .. | **100·0** | **18·6** | **61·1** | **20·3** | .. | **100·0** | **21·2** | **55·6** | **23·2** | .. | **100·0** | **11·9** | **63·1** | **25·0** | .. | **100·0** | **14·1** | **60·6** | **25·3** | .. | **100·0** | **46·1** | **43·3** | **10·6** | .. | **100·0** |

tudinal (basio-bregmatic) indices. As these values are not recorded for each skull by these two authorities, it was necessary to work out the indices from the recorded measurements and to group them; so this degree of personal error was involved. The comparison afforded by this method proved so suggestive that I extended their series of 1453 "complete" skulls by adding thereto all the "complete skulls" in all other available series, accepting where recorded the indicial values given by each author. They comprise for the Predynastic Period firstly Derry's observations on Badari and Mostagedda skulls (Morant, 1935), a slightly longer series (79 "complete" skulls) than that of Stoessiger (1927) for this period, which is so important on account of its great antiquity. Secondly, comes Fouquet's (1896 and 1897) series (101 "complete") from El Amrah, Beit Allam, Nagada (South and North), Kawamil and Guebel Silsileh, and thirdly Fawcett and Lee's (1901–02) Nagada series (314 "complete").

Motley's (Morant, 1925) First Dynasty "court officials" series fills out our knowledge with 44 "complete" skulls at that point. Thomson and Maciver's longest series of 312 "complete" skulls embraces material from the Sixth to the Twelfth Dynasty; it includes a very chequered period in Egyptian history. Their series gives us a conspectus of the population over this interval. Woo's (1930-31) small series of 69 "complete" skulls belonged to the Ninth Dynasty, and it could have been clumped with Thomson and Maciver's series, but then we should obscure its valuable picture of the diversity in population at the time in question. Its serial position in our graphic records can therefore be represented before or after Thomson and Maciver's series; I have put it in front. Collett's (1933) series of 177 "complete" skulls from the Twelfth to Eighteenth Dynasty is interpolated between Thomson and Maciver's earlier group (312 "complete") embracing the Sixth to Twelfth Dynasties, and their later group (153 "complete"), embracing the Twelfth to Fifteenth Dynasties.

The material for the Eighteenth to the Twentieth Dynasty is particularly rich, including Schmidt's (1888) Denderah and Abydos crania (66 "complete"), which seem to be regarded (Morant, 1925) as, on the whole, earlier than Schmidt's (*loc. cit.*) Thebes crania (250 "complete"). In addition there is Thomson and Maciver's series (204 "complete") from Shekh Ali (between Hou and Denderah) and Oetteking's (1909) rather agglomerate group (167 "complete") attributed to the Eighteenth Dynasty. For the Thirtieth Dynasty and Ptolemaic Period (168 "complete") as well as the Roman Period (99 "complete"), I am unable to go beyond the data of Thomson and Maciver; and, for comparison with all these series covering the pre-Christian era, the only group in the Christian era I can procure is Schmidt's (*loc. cit.*) series of Modern Crania (141 "complete").

Thus, in all, cephalic and altitudinal indices of 2861 skulls were secured

grouped in eighteen different series. Unfortunately I did not have the advantage of Miss Davin's long series of upwards of 1700 individuals from the Twenty-sixth to Thirtieth Dynasties (Morant, 1925), whose incorporation would amplify our knowledge of that era. In the same way we need

TABLE II.

*Gross Analysis of all the available "Complete" Egyptian Skulls to show the Percentage Distribution of all Nine Sub-groups.*

*Whole Series.*

| | Hypsi-cephalic. | Ortho-cephalic. | Chamae-cephalic. | Total. | Percentages. |
|---|---|---|---|---|---|
| Dolichocephalic . | Nordic **17·7%**<br>280<br>35·5% | Brown **60·2%**<br>952<br>59·1% | Bush and Boskop **22·1%**<br>350<br>76·6% | 1582 **100·0** | **55·3** |
| Mesaticephalic . | Hybrid **35·1%**<br>381<br>48·3% | Hybrid **55·0%**<br>598<br>37·2% | Hybrid **9·9%**<br>108<br>23·3% | 1087 **100·0** | **38·0** |
| Brachycephalic . | Armenoid **66·7%**<br>128<br>16·2% | ?Mongol **30·7%**<br>59<br>3·7% | ?Oriental Negrito **2·6%**<br>5<br>1·1% | 192 **100·0** | **6·7** |
| Total . . | 789<br>100·0 | 1609<br>100·0 | 463<br>100·0 | 2861 | |
| Percentages . | 27·6 | 56·2 | 16·2 | | 100·0 |

more information, than is at present forthcoming, concerning the population at selected intervals during the Christian era, but the information is adequate for our present purpose.

Even when we have divided a given community or series of communities into nine such mathematically determined groups, the problem remains of discovering whether each of these groups represents a human racial type; or whether there may not be two racial types occupying one and

the same compartment of our table. I hope to show that the dolicho-hypsicephalic compartment is Nordic, that the dolicho-orthocephalic is Brown, and that the dolicho-chamaecephalic is composed of both Bush and Boskop elements; that the brachy-hypsicephalic compartment is Armenoid, and that the brachy-orthocephalic and brachy-chamaecephalic compartments are occupied either by hybrid forms or by racial types (? Mongol and ? Oriental Negrito) as yet undefined as such.

As the brachy-orthocephalic and brachy-chamaecephalic groups are the least numerous of all the groups, accounting together for not more than 4·8 per cent. of the total, their contribution to the racial story in Egypt is not very considerable, and is greatly outweighed by those of the other groups. They will not therefore be further considered in the body of the article.

This study was in preparation for the press when Dr Robert Broom drew my attention to Dixon's (1923) thorough and pioneer study of the races of mankind along lines similar to those I had been pursuing independently. Miss Wilman sent me her copy of this book, and as my conception of human "types" and their derivation differs in detail rather in general outline from that of Dixon I have set my conception out in the accompanying tentative diagram (see fig. 1). On the other hand I sympathize whole-heartedly with the craniometrical principles underlying Dixon's far more exhaustive survey, which has anticipated our gradually evolving procedure here in South Africa.

The gap in Dixon's racial concept, to my mind, is that it took no account of Sergi's cranial-form method of diagnosis, whose value has been so greatly increased by Frassetto's (1909–18) placing it on the more secure basis of the three phases (foetal, infantile, and adult) of bone growth as exhibited respectively by the frontal, parietal and occipital bones constituting the calvaria of the skull (Gear, 1929). Thus, we can agree with Dixon's definition of the Nordic (or Caspian) type as D-H-L-(dolicho-hypsicephalic leptorrhine), and the Armenoid (or Alpine) type as B-H-L (brachy-hypsicephalic leptorrhine), but his neglect of *orthocephaly* as a racial feature has deprived his work of a degree of exactitude it would have otherwise attained. Dixon's technique was right but his "typing" was wrong. The Brown (or Mediterranean) race is not chamaecephalic, nor is the Negro race hypsicephalic; similar reservations affect his interpretation of racial types in Asia as well as in Africa, but these we have no need to discuss.

### 3. Length-Width Fluctuations.

Comparing these Egyptian cranial groups, which fluctuate so greatly in size, it seemed simplest to reduce the numbers for dolicho-, mesati- and

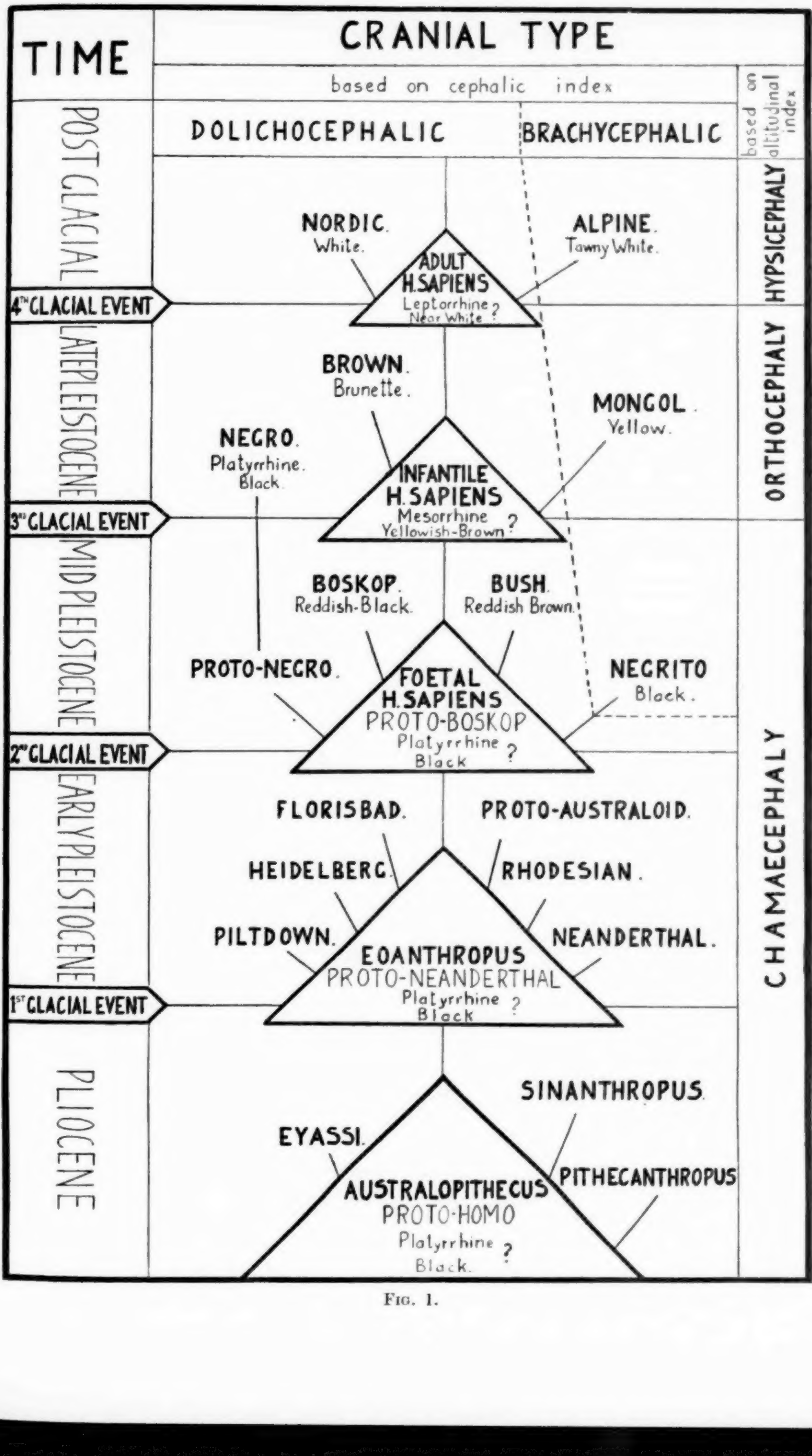

TIME
CRANIAL TYPE
based on cephalic index
based on altitudinal index
DOLICHOCEPHALIC
BRACHYCEPHALIC
POST GLACIAL
LATE PLEISTOCENE
MID PLEISTOCENE
EARLY PLEISTOCENE
PLIOCENE
4TH GLACIAL EVENT
3RD GLACIAL EVENT
2ND GLACIAL EVENT
1ST GLACIAL EVENT
HYPSICEPHALY
ORTHOCEPHALY
CHAMAECEPHALY
NORDIC. White.
ALPINE. Tawny White.
ADULT H.SAPIENS Leptorrhine Near White ?
BROWN. Brunette.
MONGOL. Yellow.
NEGRO. Platyrrhine. Black.
INFANTILE H.SAPIENS Mesorrhine Yellowish-Brown ?
BOSKOP. Reddish-Black.
BUSH. Reddish Brown.
PROTO-NEGRO.
NEGRITO Black.
FOETAL H.SAPIENS PROTO-BOSKOP Platyrrhine Black ?
FLORISBAD.
PROTO-AUSTRALOID.
HEIDELBERG.
RHODESIAN.
PILTDOWN.
NEANDERTHAL.
EOANTHROPUS PROTO-NEANDERTHAL Platyrrhine Black ?
SINANTHROPUS.
EYASSI.
PITHECANTHROPUS
AUSTRALOPITHECUS PROTO-HOMO Platyrrhine Black. ?

FIG. 1.

brachycephals (long, medium and short heads) on the one hand, and hypsi-, ortho- and chamaecephals (high, medium and low heads) on the other hand to percentages. The degree of reliance, that can be placed upon these percentages for each group, naturally depends upon the liberality of the sample available for the period in question. No distinction has been drawn between populations; all are included whether from Lower or Upper Egypt or from Nubia. Nor has any discrimination been made concerning sex; all skulls giving these three measurements have been employed. The picture they afford is therefore a composite one.

The result is shown in the accompanying chart (*vide* Plate VIII), which portrays, contrarily to Morant's concept, and those of practically all other observers an amazing *fluctuation and diversity in cranial types in Egypt throughout its whole history.* None the less, the fluctuation in these characteristics of the Nile Valley population over some seven or more millennia takes a tolerably systematic form. The dating of the eighteen series I have followed is taken from Hammerton (1927 *b*), and has no special importance seeing that we are concerned with a general sequence of anthropological events, *rather than a correlation with specific dates.* According to Petrie (1927) the Predynastic interval covered four epochs: Badarian (15,000–10,000 B.C.), Amratian (10,000–8000 B.C.), Gerzean (8000–6000 B.C.), and Late Predynastic (6000–4000 B.C.). Even if more conservative reckonings are followed, it is evident that the time-period embraced by the chart is very extensive and that the dates are only relative. The chart is not intended to give, nor in the nature of things can it give, any other than an approximate statement concerning the physical changes which the Egyptian population has sustained; for that we would need not 3000 but rather 3,000,000 skulls; but it does outline the nature of those changes. It also indicates how our knowledge of the Egyptians may be greatly amplified by further comparative indicial analyses, at the same time as it calls for indefinite expansion of the available series—not only as regards skulls but other bones also—in the interests of more detailed scientific accuracy.

### a. *Brachycephaly.*

The first striking feature exhibited by the tables and chart is the relative poverty of brachycephals in the Egyptian population. Down to the dynastic period their number is scarcely appreciable. In the first six considerable samples (comprising in all 858 "complete" skulls) from this extensive era covering a millennium *or more* in time, we never find as much as 2 per cent. of the population brachycephalic. The short heads generally account for one in every hundred of the people, or may be entirely absent, according to the sample. If the type were not so

distinctive these few predynastic brachycephals would have evaded observation completely.

In early dynastic times there is a sudden but small increment of this square-headed racial element, which then accounted for the moderate amount of over six (in some 11·6) per cent. of the people. As we trace this element in subsequent population samples, it fails to establish itself, but tends to decrease and has thus withdrawn or dispersed itself, so as to account for only three (and in some samples scarcely two) per cent. of the people, *i.e.* one-half or less of its original early dynastic strength.

At the period of the New Empire (Dynasty Eighteen *et seq.*), however, the brachycephals return to their previous force, and we find population samples reminiscent of the early dynastic period in respect to brachycephaly; they again become sufficiently frequent to account for over seven (and almost twelve) per cent. of the individuals found in certain groups of that powerful period.

Once more the brachycephals prove incapable of establishing themselves; for, when series of the population in the late dynastic (Dynasty Thirty and Ptolemaic) period are examined, they account for only six per cent.; or, once again, approximately half of the percentage they claimed on occasion a millennium and two millennia earlier. During the Roman period, however, we witness history again repeating herself with a re-entry of the brachycephalic element into the Nile Valley repetitional of that seen in the New Empire and the Early Dynastic Period. The influx of this alien and—unless continually recruited—unstable population element has presumably continued and increased during the Mohammedan era to such purpose that, amongst the modern inhabitants of Egypt, *nearly a quarter of the people are brachycephalic.*

The impact of brachycephaly upon Northern Africa, in which the Egyptian population constitutes merely a sample capable of chronometrical arrangement, has been in the form of an increeping and receding but quietly swelling tide. Six or seven thousand years ago it dribbled in to constitute less than 2 per cent. of the population, and then fell away almost completely; four or five thousand years ago the ripple tripled and in parts quintupled its volume, the backwash being now equal to or slightly greater than the trivial crest of the two millennia back; about three thousand years ago the swell once more returned at its previous maximum intensity and left a backwater at twice its recent height. Upon the inundation so established the last two thousand years of time have piled up, chiefly through Moslem invasion, a surge of brachycephaly but still standing only twelve times the height of its original dribble now almost hidden in the mists of antiquity.

Our second table shows that of the 2861 Egyptian skulls, only 192 (or

6·7 per cent.) are brachycephalic. Of these brachycephals the majority (66·7 per cent.) are hypsicephalic, but many (30·7 per cent.) are orthocephalic and a few (2·6 per cent.), especially in early dynastic times, are chamaecephalic. Hitherto most of the unsettlement in ancient times in the Near East and the concomitant racial changes and cultural development have been attributed to these square-headed, hypsicephalic, Armenoid folk. If this had actually been the truth then post-Mohammedan times should have witnessed the climax of Egyptian effulgence. From the physical anthropological point of view on the other hand, if nearly 25 per cent. of such types have had so little effect in that direction in modern times, it seems fantastic to postulate that those lesser and gradually diminishing percentages (as we trace them backwards) of brachycephals in ancient times hold the key to the successive rises and falls in the power and pomp of Egypt.

Since it has been customary for many years to invest this physical type and its oriental homeland with preponderant cultural significance, it is fitting that the precise proportion of the Asiatic element should be noted before considering any other racial aspects. The specificity of the type has made it simple for the anthropologist to isolate, and the comparative regularity and steadiness of its undulant advance in Egypt down the ages affords us a datum line, as it were, for the measurement of other invading racial influences.

b. *Dolichocephaly.*

When we look at the curves of dolichocephaly and mesaticephaly we are faced, by contrast, with *an extraordinary series of fluctuations*—especially in the middle part of the chart—which are more or less reciprocal to one another on account of the relative stability of our brachycephalic datum line. Despite these fluctuations, no less than 1582 skulls or 55·3 per cent. of the total are dolichocephalic, whereas only 1087, or 38·0 per cent., are mesaticephals.

The majority of Egyptians at practically all stages of their history have been, and even to-day are therefore dolichocephalic; but the percentage of long-headed people in the population has fluctuated greatly between its predynastic peak of 74·3 per cent., and its diminished modern altitude of 41·1 per cent.

The second significant fact which emerges relative to dolichocephaly in Egypt is that its fluctuations are to some extent concurrent with, but occur also *independently* from brachycephaly; they are not resultant from brachycephalic mixture alone in Egypt.

A third fact of no less importance is that amongst the Egyptians a low incidence of dolichocephaly and a high incidence of mesaticephaly represents *a temporary and highly unstable population situation,* which

crystallizes out with great rapidity into the reversed state. But successive experiences in mesaticephalization gradually lower the resilience of dolichocephaly to such an extent that it recaptures only slowly and far from equally its original prestige.

We can assume either that a highly mesaticephalized population was making repeated inroads into Egypt only to meet with rapid absorption by local dolichocephals; or that a people, not brachycephalic or mesaticephalic, but *dolichocephalic* made these inroads; and, by racial intermingling with both foreign brachycephals and indigenous dolichocephals, could produce a temporary mesaticephalic preponderance. Out of this *mesaticephalized* population many dolichocephals and few brachycephals emerged along with a reserve of approximately 25 to 30 per cent. mesaticephals, the mixed multitude of racial hybridization.

As we are ignorant of any genuine mesaticephalic race, and the condition of mesaticephaly is demonstrably an *unstable* one in Egypt, the second of these explanations is the more probable. It is also corroborated by two facts: first, that away back in early predynastic times, when the population was least disturbed by brachycephalic influence, it was *unstable* and settling down after a similar *mesaticephalization*; and second, that in early predynastic times, if Motley's small group is any guide, the people —or a portion of them—were also suffering from such a *mesaticephalization* in a similar *absence of brachycephaly*.

Actually the times, when dolichocephaly swoops into its lowest, or 30 per cent., troughs and mesaticephaly soars to its tallest, or 60 per cent. crests, coincide with Woo's (*loc. cit.*) Ninth Dynasty series and Schmidt's (*loc. cit.*) Eighteenth Dynasty series, which are also marked by brachycephalic elevations. It will, however, be noted that no such concurrence of brachycephaly with lowered dolichocephaly and elevated mesaticephaly is found in Motley's (Morant, 1925) First Dynasty series, nor does such a lowering of dolichocephaly and elevation of mesaticephaly coincide with the crest of brachycephaly in Schmidt's later Eighteenth to Twenty-first Dynasty series and his Modern series.

These abrupt intrusions of *mesaticephaly-producing dolichocephalic* (and brachycephalic) peoples, whether they arrive separately or together, mark calamitous periods of public stress in Egypt, which were followed by outbursts of national enterprise and of artistic and structural achievement. However much innate capacity the indigenous population may have possessed for such progress it is apparent that, from the outset and through the entire historical period, they have been assisted therein by alien dolichocephals *more frequently and to a greater extent* than by brachycephals.

Of all the dolichocephalic Egyptian people the majority (60·2 per

cent.) are orthocephalic (*vide* Table II); the next largest group is chamaecephalic (22·1 per cent.); the smallest group is hypsicephalic (17·7 per cent.). These groups account respectively for 59·1 per cent. of the orthocephals, 76·6 per cent. of the chamaecephals, and 35·5 per cent. of the hypsicephals; they constitute therefore at least three markedly divergent human types in respect of relative skull height, although they are all relatively long-headed people. Hence in Egypt there were at least *three* dolichocephalic races in addition to the brachycephalic race.

### c. *Mesaticephaly.*

In early predynastic time, as we have seen, the general trend of population events was towards a "settling" of mesaticephaly from approximately 30 down to 25 per cent., and a rising of dolichocephaly from below 70 per cent. up to approximately 75 per cent. of the population. Had further dolichocephals and brachycephals never arrived a relative population-proportion of this type may well have been established.

On the contrary when the postulated dolichocephals came, prior to early dynastic times, the mesaticephalic population jumped to 45·5 per cent. in the First Dynasty, and could not fall below 33·5 per cent. during the First to Sixth Dynasty in the presence of 6 per cent. of incoming brachycephals.

In the Ninth Dynasty intruding dolichocephals and brachycephals caused so much disturbance in cephalic proportions that in a select area, such as the Gebel Sedment colony, the mesaticephalic proportion soared to *fifty-eight* per cent. This situation was not typical of the whole country because elsewhere, during the period from the Sixth to the Fifteenth Dynasty, the general mesaticephalic proportion was approximately *thirty* per cent. just as in Badarian times, about three thousand years earlier.

Then, about the time of the opening of the Eighteenth Dynasty, another of these soaring mesaticephalic incidents up to the height of *sixty-two* per cent. presages a general shift of the whole population in the mesaticephalic direction. Thus when the slowly returning brachycephals reach their peak at the tail-end of this colourful era, the general percentage of mesaticephals is on the wane, but still accounts for *forty-four* per cent. of the people. Giving way, like brachycephaly, before victorious dolichocephaly, mesaticephaly recedes once more to nearly *thirty* per cent. in the Thirtieth Dynasty and Ptolemaic times. With the readjustments of population in Roman times it again ascends slightly and then gives ground, with falling dolichocephaly, to the Mohammedan rise in brachycephaly we have already studied.

These facts illustrate the fashion in which *mesaticephaly has served as a biological buffer state* between dolichocephal and dolichocephal and between dolichocephal and brachycephal, more particularly in that significant historical period between 3500 and 1000 B.C. That period marks the rise of ordered civilizations and the gradual transition of historical events from the realm of agglutinative conjecture into the clear light of coherent, interdependent record.

Of the Egyptian mesaticephals the majority (55 per cent.) are orthocephals, but they only constitute a little over a third (37·2 per cent.) of all the orthocephals. The next largest group of mesaticephals (35·1 per cent. or a little over a third of this class) are hypsicephals, and it should be noted that, few as they are in relation to the orthocephals, these particular hypsicephals are the most numerous of the hypsicephals, and account for nearly one half (48·3 per cent.) of the category. The smallest group of mesaticepals (9·9 per cent.) are the chamaecephals; they form a small portion (23·3 per cent.) of all the chamaecephals, but cannot represent the racial type of that group. The various sub-groups of mesaticephals, dolichocephals and brachycephals will be better understood when the length-height fluctuations have been discussed.

## 4. Length-Height Fluctuations.

Having followed the fluctuations in the length-width relationships exhibited by Egyptian skulls over the last 7000 years, and having witnessed thereby the diminutive effect of the pulsations of Asia upon ancient Africa, it becomes important to examine to what extent the characteristics of these dolichocephalic and brachycephalic invaders are mirrored in the length-height relationships of the same skulls.

### a. *Orthocephaly.*

Just as the majority of Egyptian skulls are dolichocephalic (or relatively long-headed) during their long and eventful history, so too we find an even greater majority were of medium height, *i.e.* orthocephalic. The orthocephals account for 1609 skulls, or 56·2 per cent. of the whole number.

Of these Egyptian orthocephals the same group, as we found to constitute 60·2 per cent. of the total dolichocephalic population, represents no less than 59·1 per cent. of the total orthocephalic population. The remainder of the orthocephals analysed in Egypt are chiefly (37·2 per cent.) mesaticephalic, and to a diminutive extent (3·7 per cent.) brachycephalic. These mathematical facts make it abundantly clear that the fountain of Egyptian orthocephaly was long-headed in nature.

At the opening of our story the orthocephals embraced approximately

60 per cent. of the Egyptian people, and the tendency then was for their number to increase concurrently with dolichocephaly. With the coming of the early dynastic brachycephals, however, the percentage of orthocephals straightway fell by about 9 per cent., and went on falling to almost 11 per cent. below its pre-dynastic peak of 67·1 per cent. Despite such modifications the comparative regularity of the orthocephalic curve throughout the entire period is one of the most impressive features of the chart.

The orthocephals sharply and regularly recovered during Dynasty Twelve and *those subsequent thereto* until they overtopped their known pre-dynastic record by nearly 3 per cent. This hey-day of orthocephaly terminated with the dolichocephalic and brachycephalic inroads before and during the New Kingdom, when it (orthocephaly) fell to 55·6 per cent. Once again a recovery was registered, and the proportion rose to reach 63·1 per cent. in Ptolemaic times. Since then, confronting the gradually increasing ascendency of brachycephaly and concurrent hypsicephaly, the orthocephals have steadily diminished, and in recent times account for only 43·3 per cent. of the population.

The parallelism between dolichocephaly and orthocephaly down the corridors of historic time leaves no question but that *the fundamental skull-type characteristic of the Egyptian population and therefore of the Brown (or Mediterranean) race was ortho-dolichocephalic.* Thus Dixon's (1923) classificatory scheme is not sufficiently elastic to group all the human racial types. We also learn from this anthropometrical *résumé* that, when a considerable number of dolichocephalic and brachycephalic aliens become incorporated in this indigenous ortho-dolichocephalic (right or medium long-headed) Brown population, they leave an ineradicable impression upon the subsequent population; but they are not able to swamp its fundamentally orthocephalic nature unless they come in sufficient numbers to replace it. The autochthonous, ortho-dolichocephalic racial characteristics are sufficiently dominant in the offspring of the racial crossings, which take place, to reassert and maintain their diminished but still dominant prestige. The present phase of Egypt's population story is therefore merely one, where brachycephaly is commoner than at successive but similar earlier periods.

These facts concerning Egyptian dolichocephaly and orthocephaly reaffirm the conclusions of Elliot Smith (1911), based upon the examinaton of Egyptians from early dynastic times down to the present-day population:

"The study of this extraordinarily complete series of human remains, providing in a manner such as no other site has ever done the materials for reconstruction of the racial history of one spot during more than forty-five centuries, made it abundantly clear that the people whose remains were buried just before the introduction of Islam into Egypt

were of the same flesh and blood as their forerunners in the same locality before the dawn of history. And nine years' experience in the Anatomical Department of the School of Medicine in Cairo," continues Elliot Smith, "has left me in no doubt that the bulk of the present population of Egypt conforms to precisely the same racial type, which has thus been dominant in the northern portion of the Valley of the Nile for sixty centuries."

The physical features of the endogenous, Brown, racial type have been described by Sergi (1908) and by Elliot Smith (1923), and may be summarized as follows: They are of medium height and slender, verging on the effeminate or juvenile in bony structure and bodily physique; the hyposthenic type. Their glabrous brunette bodies have scanty facial hair, except for a small moustache and a chin tuft; but their heads are covered with glossy, jet-black hair. The iris is deep brown owing to a considerable retention of body pigment, but the conjunctiva is white. The skull is long, 180–190 mm., and relatively narrow (dolichocephalic), of relatively moderate height (orthocephalic), smoothly or obtusely pentagonoid when viewed from above, and of moderate capacity (mesocephalic). The eyebrows are poorly developed, but the fairly broad forehead rises erect and full above them, and the occiput is bulged out behind into a prominence. The orbits are horizontal, ellipsoidal, and have thin margins. The cheeks are narrow and their bony supports flattened laterally; the straight nose is of moderate elevation and length. The small jaws do not project and the chin is pointed. The face as a whole is straight, short, of moderate width and of ovoid form. The Brown type—in Frassetto's terminology—is a *juvenile* human type, as compared with the *foetal* Bush and *adult* Nordic types.

### b. *Hypsicephaly.*

Our second table shows that the hypsicephals of Egypt are a composite group. We have already seen that only 6·7 per cent. of the people were Asiatic brachycephals, and that the majority (66·7 per cent.) of these were hypsicephalic; but they only constitute 16·2 per cent. of the total immigrant *hypsicephals* discovered. More than twice as many (35·5 per cent.) are dolichocephalic, and the greatest number of all, nearly one-half (or 48·3 per cent.) of the hypsicephals are mesaticephalic hybrids. Unless we claim that all the mesaticephals are of brachycephalic origin—a thesis not supported by the graph analysis, which showed a distinctive reciprocation between dolichocephaly and mesaticephaly—then the *story of hypsicephaly in Egypt is primarily and fundamentally a dolichocephalic epic.*

The fluctuations in relative head-height amidst the Egyptians constitute in many ways the most crucial of all those, which we are called upon to consider. At the earliest period of which we have cognisance 30 per cent.

or more of the people were hypsicephalic (high-vaulted); but during the long interval which intervened before the First Dynasty, the proportion of elevated heads steadily decreased until they accounted for (if Motley's rather select group can be accepted as representative) less than 10 per cent. of that rather aristocratic portion of the population at the opening of the dynastic epoch. Such a fall can be explained only by genetics!

With the coming of the early dynastic brachycephals the proportion of high-vaulted individuals increased *out of all proportion to the number of brachycephals.* Thus, although we now find 6·1 per cent. brachycephals, we encounter 24·4 per cent. hypsicephals. Nor does the phenomenon end at this point; for although the brachycephalic proportion now starts receding, *the hypsicephalic proportion goes on increasing,* until it reaches and even surpasses (at 34·6 per cent.) the record (34·2 per cent.) height it had sustained in the earliest predynastic series known. In Woo's Ninth Dynasty sample it culminates at the zenith of 47·8 per cent. Having achieved this spectacular climax, the high-vaulted folk rapidly dwindle until they again account—as they did a millennium previously—for little more than 10 per cent. of the population at the opening of the New Empire period. But it is significant that even at this nadir or trough there are *three times as many hypsicephals as there are brachycephals.*

With the reflux of the brachycephals (11·6 per cent.) into Egypt at this New Empire time the hypsicephals again increase numerically out of proportion to the brachycephalic percentage to as much as 21·2 per cent., only to fall away to 11·9 per cent. in Ptolemaic times. Finally, with the repetitional influx of brachycephals during Roman times and the Mohammedan Era the hypsicephals once more increase—and once more out of all proportion to the percentage of brachycephals (24·1 per cent.)—and come to account to-day for no less than 46·1 per cent. of the people, outrivalling even the local orthocephals (43·3 per cent.).

It is clear from the alterations in the high-vaulted population that they denote dramatic racial percentage changes, whose correct interpretation is most important for understanding the human racial story in Africa. In this interpretation it is important to recognize that out of 2861 skulls in the series 789 (or 27·6 per cent.) are hypsicephalic, whereas only 192 (or 6·7 per cent.) are brachycephalic. Thus there are *more than four times as many hypsicephals* as there are brachycephals. I have already pointed out that the first dribble of the brachycephalic tide into Africa during the predynastic epoch was inadequate to disturb seriously the proportion of dolichocephals. It is obvious therefore that, whatever might be argued about later samples the high hypsicephaly encountered at the time when Egypt was emerging from the darkness of the Stone Age into the half light of then dawning civilization cannot be charged to the Orient. This

earliest or first era of hypsicephaly, as I have termed it, is an era of virtually *pure dolichocephalic hypsicephaly.* Hence its presence must be due to some dolichocephalic race—or a mesaticephalic one, if such were known —that is, hypsicephalic. *This dolichocephalic hypsicephaly can only be explained as resulting from Nordic invasion.* If further proof of the assertion were needed, it is found in the fact that the percentage of hypsicephaly is highest in Derry's group, where brachycephaly is absent; it is already appreciably lowered in that predynastic group (Fawcett and Lee) where the brachycephals are most numerous. Dixon's (*loc. cit.*, pp. 192-198) analysis led him to the same conclusion of a Nordic (or Caspian) invasion of predynastic Egypt.

Despite reinforcement by the small amount of brachycephalic hypsicephaly entering Egypt during predynastic times, *this dolichocephalic hypsicephaly was threatened with submergence* or even extinction, until the coming of the early dynastic invaders. The first moderate or early dynastic influx of the brachycephalic hypsicephals *must have been preceded, accompanied and followed by early dynastic intrusions of dolichocephalic hypsicephals.* This is shown by the dolichocephalic mesaticephalization in Dynasty One (Motley's group), and also by the early dynastic outburst of hypsicephaly, which is far too volcanic to be assigned to these brachycephals or their predecessors, or to both alone. That uprising would, however, be explicable, if the cautious early dynastic brachycephals (who, from the work of Elliot Smith and other investigators, are known to have been of the Armenoid type), when they made their first appreciable inroads into Egypt, followed after and associated themselves with the adventurous hypsi-dolichocephals, and if both invading racial types allied themselves with the diminishing minority group of hypsi-dolichocephals already in Egypt in preference to the locally preponderant Brown ortho-dolichocephals.

This explanation is more than conjectural when we recall that the Nordics constitute the only living race of hypsi-dolichocephals. The interests of the intrusive Nordic and Armenoid elements and the diminishing local Nordic element must have been more cognate and closely related to one another than those of the indigenous population, not only because of their sharing a minority position in the population as a whole, but also because of a greater community of political, commercial and artistic interests than they found in the greater part of the indigenous population.

The alignment of the foreign elements with one another is also shown by the fact that the numbers of people with high-vaulted heads increased momentously up to the Twelfth Dynasty, and were then swept away with extreme suddenness to practically one-half of their former eminence. They dwindled in significance over the next millennium until the resurgence of the New Kingdom, whose diminutive hypsicephalic rise, and

subsequent falling away, we have already discussed. They appear to have been looked upon and treated as foreigners when they became too prevalent.

Because it interrupts Thomson and Maciver's Dynasties Six to Twelve group, and, on account of its peculiar and specialized features, I hesitated to introduce into the graph the results secured from T. L. Woo's (*loc. cit.*) paper on the group of seventy-one skulls (69 "complete") of the Ninth Dynasty excavated at Gebel Sedment, seventy miles south of Cairo, and overlooking the Fayum. Some also may argue that it, like others, is too small to be representative of the whole population, and we can agree with such criticisms; but it is a striking sample. This small series comprises 30·4 dolichocephals, 58 per cent. mesaticephals, and 11·6 per cent. brachycephals. Of these no less than 50·7 per cent. are hypsicephals, while 47·8 per cent. are mesaticephals, and only 1·5 per cent. are chamaecephals. This single *chamaecephalic* skull has a length of 194 mm. (see later description). The almost entire absence of the chamaecephalic element in this select cemetery, the relatively high percentage of brachycephals for this period of so-called "Asiatic" invasion, and the overwhelming number of hypsicephals all go to show the actual community of interests in life and death that existed between the Nordic and Armenoid sections, and their severance from the "lower strata" of the population in the troubled interval preceding the "Middle Kingdom."

I shall not interpolate a description of the Armenoid race; that type has already received adequate attention in Egypt. Von Luschan, who identified the type in Western Asia, noted the tawny white skins, hirsute faces, straight hair, dark brown eyes, narrow aquiline noses and very short, high heads of the Semitic type; they belong with the Alpine brachycephals of Europe to one racial stock. But it is necessary for the development of our story, that I should summarize briefly, the salient features of the Nordic race, so that we may be assisted in interpreting our chart and other data.

The Nordic race has been variously, and in the main, very partially depicted by anthropologists owing to Sergi's (1897, etc.) holding the erroneous idea that a single human race could present several divergent forms of skull. No thoroughgoing description of the pure form is accessible, but the guiding syntheses of metrical and non-metrical features attempted by Sergi (1908), Montandon (1933) and Elliot Smith (1934) are most valuable. Interracial hybrids are the individuals responsible for the divergent forms of skull; hybrids can take up almost any medley of mixed cranial and other racial characters; but it is obvious that we cannot proceed far with the study of these mixed forms, until we understand the typology of the pure races that produced them.

The Nordic race then, as far as it has been isolated, is a very tall, large-boned, physical type, individuals being long and gaunt or asthenic in build. Their blond, pinky-white bodies are hirsute, being clothed with fine, downy hairlets, which give place to profuse, fair hair, especially in the armpits and groins (and the chest in the male sex) at puberty; their heads (and their faces in the male sex) are well-covered with a luxuriant growth of golden, wavy hair. The iris is deep blue, green or grey in colour, so great has been the loss of body pigment; the conjunctiva is pinky-white. The skull is very long (185–195 mm. approximately), but is relatively narrow (dolichocephalic), ellipsoidal (with parallel sides—the *pelasgic ellipsoidal* of Sergi) when viewed from above, of great height (hypsicephalic) and of great capacity (macrocephalic). Eyebrow ridges are present to a moderate degree, especially in the male, but the forehead is broad and full, the cranial sagittal contour sweeping in a regular curve to its post-bregmatic vertex, and dropping therefrom posteriorly in a regular but more rapidly falling arch to the unobtrusive expanded occiput. The square orbits separated by a narrow interval almost completely underlie the wide forehead, and thus the external orbital processes are reduced and the cheek bones medially displaced so that they cannot be seen from above. The rugged face is in this way elongated and narrow (leptoproscopic) in harmony with the skull; the high-bridged, narrow, elongated nose is harmonically leptorrhine. The profile of the long face, save for the projecting or aquiline nose is vertical or even concave forwards, ending in a prominent chin due to the retracted alveolar margins of the large and sturdy jaws. The oral region is finely modelled and non-projecting, the lips are apparent but are narrow and not protruded. The face as a whole is of a mature type corresponding with the *adult* forms of the bones. The body is fully erect and, because of the rotation backward of the trunk on the femora, the buttocks do not protrude unduly posteriorly, and the compensatory curves of the spinal column are fully developed. As a whole the Nordic human type bears an *adult* or gerontomorphic relationship to the more nearly pedomorphic or *juvenile* Brown type comparable with the gerontomorphism displayed by the Boskop type *vis-à-vis* the Bush type (*vide* later description).

This flaxen-haired, white race furnished the hypsi-dolichocephalic element, which entered Egypt before the Badarian period, and produced *the first era of hypsicephaly*, an era very fateful in the destinies of Egypt. The clear-cut nature of the hypsicephalic tempests in Egyptian history makes it convenient to subdivide our chart into four corresponding eras. Subdivision of our time chart in terms of hypsicephaly is not necessarily the most happy of selections, but it has the conjoined merits of summarizing simply the anthropological facts and of drawing attention to *the dual*

*nature of the immigrant hypsicephalic stream* into Egypt *after* the first or purely dolichocephalic invasion.

During the period under consideration there have been four hypsicephalic eras, the last three being of a combined dolichocephalic and brachycephalic character; but the dolichocephalic-mesaticephalic events suggest and the nature of the hypsicephaly proves that these combined events were consistently precipitated by an essentially dolichocephalic people, especially in the time period represented by the central portion of our chart.

Having noted the several hypsicephalic eras in Egypt and their primarily dolichocephalic (Nordic) nature it is important to recognize that similar physical phenomena must have characterized the whole of the ancient Near East. I am well aware that Childe (1927) says:

> Not even the most extreme German archaeologists claim that the Nordic hosts had reached the Caucasus, still less Mesopotamia, at such an early (3000 B.C.) date.

But both anatomical and linguistic facts support in reality that very contention. Amongst 135 skulls, excavated from the ancient mound of Damghan at Tepe Hissar, south-east of the Caspian Sea and ranging in date from 3500 to 1500 B.C., only *one* was brachycephalic; amongst the four skulls from Anau of the second millennium in Kurgan there are *no* brachycephals. The same applies to the three skulls from the third city of Hissarlik in Asia Minor; the sixteen from Hanai Tepe near Troy, the four skulls from Alishar Period IV belonging to the Hatti (Hittite) period of Boghaz Keui, and corresponding with the third city of Hissarlik, and to the seven skulls from Ur. Out of eleven skulls from Al'Ubaid there is *one* brachycephal, and in the twenty-six skulls from Kish there are *two* (*cf.* Ariens Kappers, *loc. cit.*).

Hence out of these 206 skulls, ranging in place from the Dardanelles to the Caspian Sea and the Persian Gulf, and in time from the fourth to the second millennium B.C., we find, as we found in Predynastic Egypt, that the brachycephalic (or Armenoid) element accounts for less than 2 per cent. of the population in general.

Invaders of the same long and high-vaulted Nordic type were prevalent in Mesopotamia at this period. For millennia these elaborately dressed, ornament loving, wavy-haired aliens boasted of governing "the black-headed ones" (Keane, *op. cit.*, pp. 264–65). Sayce (1930) says: "The Sumerians called themselves 'the black-headed people.' This implies that there was also a blond race in the country from which their black hair and eyes distinguished them." He proceeds to give the evidence that the pre-Sumerian people, responsible for the artistic treasures and human sacrifices in the royal tombs of Ur in Mesopotamia, were the dolicho-

cephalic, blue-eyed, fair-haired, Sanskrit-speaking *Murri*—the Amorites of later history. Keith (1927) said: "The southern Mesopotamians of the fourth millennium B.C. had big long and narrow heads; their affinities were with the peoples of the Caucasian or European types. . . . They were akin to the Predynastic people of Egypt described by Dr. Fouquet. . . . The Neolithic peoples of English Long-Barrows were also related to them —perhaps distantly; the Sumerian type made its appearance in Palaeolithic times, for one of the earliest of Aurignacian skulls—that found at Combe Capelle at Dorgogne, France—is near akin to the ancient Arab type."

Hence the phenomena we have been observing in Egypt are a true sample of population phenomena not only in Egypt but in the whole of the "fertile crescent" in the Near East. The population of Asia Minor * and Mesopotamia like Egypt was primarily Brown, secondarily Nordic, and only tertiarily Armenoid. Thus even if and when "Asiatic" intruders into Egypt came overland from Mesopotamia, as some chronologists believe, the stranger element (so far as Egyptian population is concerned) was still dolichocephalic (or Nordic) rather than brachycephalic (or Armenoid) through every phase of the Egyptian story.

The presence of projicient and long-nosed people, with curling locks and beards on ancient monuments of Mesopotamia and Asia Minor, has been regarded as *prima facie* evidence to archaeologists that the people depicted were "Asiatics" of Armenoid type. I am not stating that this view is incorrect in all cases, but the fact that Nordic people are endowed with similarly pronounced features renders the diagnosis of race from monumental records a matter for the exercise of far greater discrimination than has as yet been accorded thereto.

At no time in the history of Egypt, at any rate not during the Mohammedan epoch, is there evidence of the movement of a population of preponderantly brachycephalic type overwhelming the Near East. Even "in the latter part of the first millenium B.C. the occupants of the whole territory (Mesopotamia and Syria) were predominantly of dolichocephalic types, the Mediterranean and Caspian (Nordic) being in the majority" (Dixon, *op. cit.*, p. 253). Not until the rise and victorious movement of Jengis Khan in the thirteenth century of the present era do we find a war-like mass movement of preponderantly brachycephalic people as far

* Since presenting this paper I have received W. M. Krogman's paper on "Cranial Types from Alisar Hüyük and their Relations to other Racial Types, Ancient and Modern, of Europe and Western Asia" in Oriental Institute Publications, vol. 30, where he demonstrates that the earliest population in Asia Minor was dolichocephalic and discusses the non-Mediterranean, long-headed or "Nordic" skulls found in Asia Minor prior to the intrusion of brachycephalic types there."

west as Poland and Hungary, and in the following two centuries, under the form of the Turkish empire, across the Bosphorus and almost to Vienna.

This does not mean that the Alpine (or Armenoid) race had no influence on the course of events in the Near East and Europe; on the contrary the gradual and increasing percolation of this Asiatic type into Europe during Neolithic times is well known. Sergi's data (*vide infra*) indicate that they could account for as much as 10 per cent. of the Western European population in some parts during that era. The expansion of brachycephaly across Russia and Austria into Germany, France, and the British Isles is a very ancient phenomenon; and, until we learn something definite to the contrary, it is as feasible and far more probable *to derive brachycephaly of the Near East and Egypt* via *invasions from Europe* than from Turkestan.

### c. *Chamaecephaly.*

The relative constancy of the proportion of orthocephaly and the wide fluctuations in the proportions of hypsicephaly have hitherto dominated our picture of the transformation in Egypt's population down the ages. The background of that picture is composed by the chamaecephalic elements.

The low-vaulted people are, next to the brachycephals, the least conspicuous group in the entire Egyptian community. They only account for 16·2 per cent. of the skulls considered, and of these just over three-quarters (76·6 per cent.) are dolichocephalic, while only 1·1 per cent. are brachycephalic. These brachycephalic chamaecephals are the rarest of all; they occur once in every 572 skulls and form ·017 per cent. of the whole group. Some 23·3 per cent. of the chamaecephals are mesaticephalic, and, even if we should assume that the other (dolichocephalic) alien hypsicephalic race could have had two or three times the effect of the brachycephalic race in mesaticephalizing the characteristically dolichocephalic group of chamaecephals, it is clear that, here as elsewhere, the most potent mesaticephalizing influence was the indigenous dolichocephalic Brown race. The ancestral type or types responsible for chamaecephaly in Egypt must have been one or more dolichocephalic peoples distinct from both the Nordic and the Brown types.

The divergences in the percentages of low-vaulted or chamaecephalic people, found in the three first (or early predynastic) groups depicted in our graph (viz. 3·8, 15·8 and 12·1 per cent.), show that low-vaulted people were ubiquitous in these groups, but that some of the racial groups in Egypt tended to preserve themselves clear of admixture with that physical type even at this early date.

However infrequent these chamaecephals may have been rendered at

the outset of the record, it is obvious that, as and when dolichocephalic hypsicephals diminished, there came an increment firstly of the dolichocephalic orthocephals, but secondly, and far more significantly, of the *dolichocephalic chamaecephals*. Thus, when the dynastic period opens and the hypsicephals are reduced to 9·1 per cent., the chamaecephals have already achieved their record proportion of 27·3 per cent. or more than a quarter of the population.

During the first millennium of the dynastic period when the hypsicephalic population rose up, threatening to supplant the orthocephalic indigenes, the chamaecephalic element was simultaneously threatened with entire extinction and certainly dwindled away to form less than the submerged tenth of the people. Then, as soon as the hypsicephalic intruders fall away (or become absorbed) and the orthocephalic population increases, there again emerges from its temporary obscurity the concomitant chamaecephalic element. Its subsequent history is one of steadily increasing ascendency during the New Kingdom, until it comes to account, in the Ptolemaic and the Roman periods, for approximately one-quarter of the population.

From this laboriously regained peak, comparable with that attained about 3000 years earlier at the close of the predynastic era, it has dwindled during the Christian era concurrently with the orthocephalic section of the community, in the presence of the overwhelming hypsicephalic surge, so that it constitutes to-day for the third time in 7000 years the submerged tenth of the populace.

It is appropriate at this point to inquire what is the source of this persistent and ineradicable low-headed element? It is neither Asiatic (Armenoid) nor European (Nordic) in origin, nor, as we have seen, can it be attributed to the indigenous North-East African (Brown) population. The field of our inquiry is restricted to the African continent and therein we should be enabled to discover the answer to the riddle. Unfortunately Dixon's (*loc. cit.*) confused definition of Proto-Negroid (D-H-P) and Proto-Australoid (D-C-P) types does not aid us here.

Thomson and Maciver's claim, that the Egyptian population from the earliest times was divisible into negroid and non-negroid entities, was based (*op. cit.*, p. 86) on "the modelling of the forehead, the inter-ocular width and that peculiar form of nasal aperture described by the French as *gouttière simienne*, as well as the presence of prognathism and microcephaly." They took cognizance of "Professor Kollman's theory that there was a pygmy element amounting to something like 20 per cent. of the entire population of Abydos in this archaic time," but concluded that "this appears to us to be based upon insufficient evidence, resting as it does entirely upon the occurrence of small skulls with low capacity." They

subjected the frequent instances of this kind occurring during their investigations to rigorous examination but, failing to establish correlations between such pygmy types and a pygmoid stature, felt "that at present we have no such evidence as would justify us in assuming the existence of a pygmy stock" in Egypt.

This praiseworthy caution would doubtless not have been exercised if the cranial characteristics of the genuine Negro had been better understood nearly forty years ago. Even at the present time they are imperfectly understood but, through investigations conducted during recent years, we can claim categorically that *the ortho-ovoidal* (i.e. *the moderately high and egg-shaped) form of skull represents the Negro element in its greatest purity* (*cf.* Dart, 1937 *a*). Hence the argument that there is a pygmy element in Egypt, based on a microcephalic skull type and pygmoid stature used by Kollman and supported by Thomson and Maciver's own data, has been justified by subsequent analysis of the Negro and also by the discovery of African types in Egypt, which are not Negro and ought never to have been called Negro.

On the one hand H. D. Smith (1911–12) has proven the presence of pygmoid types in Egypt. On the other hand "the earliest pictures given us by the dynastic Egyptians of the wild aborigines of the Nile Delta are engraved on slate palettes, and depict a dwarfish-like race, not unlike the Congo pygmies of to-day—differing from them only in possessing rather bigger though flattish 'Papuan' noses with bushy heads of closely curled hair" (Johnston, 1913). In this broad study Sir Harry Johnston performed a great service by gathering together numerous strands of evidence covering the wide distribution of the pygmoid African peoples and their original presence in Egypt.

Repeated evidence has been adduced concerning the physical and linguistic persistence of the Bush type in Tanganyika, Kenya, and even Abyssinia. "Anatomical, linguistic and archaeological facts here all unite in demonstrating that *the territory of the long-headed,* low-vaulted, pentagonoid microcephalic Bush race extended at one time from the Cape of Good Hope to the Red Sea*" (Dart, 1937 *a*).

The conclusions of Thomson and Maciver were almost immediately subjected to a critical, but unfortunately since that time, neglected examination by Biasutti (1905) with the aid of data secured by him from a small collection of forty-two Egyptian crania embracing specimens from the Pyramid Age down to the Roman Era. Their conclusions were also contested by Sergi (1908), to whom the authors had submitted photographs of their skulls for cranial-form determination. Biasutti joined issue with Thomson and Maciver, as did Sergi, for assuming that all specimens with a

* *I.e.* Dolichocephalic; actually they are short and narrow-headed.

low nasal index were negroid. Basing his attack on the thesis that alveolar index is much more important than the nasal index for determining negroid admixture, Biasutti concluded:

Che l'elemento negro, preso nel suo vero senso ed escludendo quindi gli elementi austro-africani e nannocefalici che sembrano giacere nello strato più profondo dell' Egitto antico, ha un' importanza trascurabile nel complesso della populazione.

This physical fact, that the real Negro had a negligible importance in the population complex of ancient Egypt, is fundamental to the understanding of Egypt and the whole question of the wanderings of human races in Africa. Even although Biasutti and others were prepared to admit that contacts of the Egyptians with genuine Negroes could have been "numerous and frequent at all times, but especially in the later epochs," there is as yet no satisfactory evidence to demonstrate the veracity of that widely accepted conception.

Describing the environment of Upper Egypt, Peet (1927) makes the important observation of its relative immunity from racial intrusion. Hemmed in by impassable deserts to the east and west, the Delta formed a buffer on the north, while "to the south lay the wild tribes of Upper Nubia and the Sudan, who, as far as we at present know, never gave Egypt any serious trouble until the time of the conqueror Piankhi in the Eighth century B.C." That the true Negro reached Egypt in appreciable quantities in Roman times is perhaps shown by the fact that Thomson and Maciver were able to discover amongst their "negroid" males at this time "a remarkable rise in cephalic index" in a small series comprising only eight specimens, five of which were platyrrhine (*op. cit.*, p. 105) and concerning whom they say: "Lastly, in the Roman period there is a striking fact that negroid men appear, who belong to a type which is superior in cranial development to that of the contemporary native" (*op. cit.*, p. 112). But even to the Romans, authentic Negroes were very little known. To Professor H. J. Tillyard I am indebted for directing my attention to Barrow's (1928) remarks. "Petronius mentions Arabians with bored ears; and Nubians are somewhat of a curiosity, Numidians and Africans were employed as letter-bearers and outriders." In his admirable description of Roman slaves, Barrow demonstrates indirectly the *negligible* influence of the Negro in racial bastardization down to that late period in the Mediterranean region.

A slight intrusion of the unalloyed Negro into Egypt during the Roman period and even the Ptolemaic period may be admitted and is corroborated by the occasional true Negro specimens discovered by Biasutti (*loc. cit.*); but it is apparent that, even at this late date, relatively few Negroes are present in Egypt, nor is there any anatomical proof that they ever entered

by force down the Nile Valley. It is far more probable that they were, as we are told, curiosities, which seem to have reached Egypt as well as Rome by *commercial avenues* from caravan communication across the Soudan or still earlier Carthaginian enterprise along the western coast of Africa. There is certainly no evidence of true Negroes emerging on the eastern seaboard of Africa before the sixth century of the Christian era: after that time they were well known to the Arabs, but they were still a curiosity to the Chinese court in the tenth century; the physical type is described elsewhere (Dart, 1937 *a*).

The point I am reiterating is that urged over thirty years ago by Biasutti (*loc. cit.*) that the "negroid" element described by Thomson and Maciver is not Negro, but is composed of "South African and dwarf-headed elements." As he puts it, "In the lowest stratum of this formation (the profoundly heterogeneous population of ancient Egypt) are found the South African or Bushmanoid type, in notable proportion, and some traces of dwarf-headed types, pygmies." Using the data of Hamy, Fritsch, Thulie and Shrubsall, Biasutti (*loc. cit.*), showed that the Bushmanoid types identified by him and recurring throughout Thomson and Maciver's series were those types already recognized by Pruner-Bey and Sergi under other names as constituents of the ancient Egyptian population.

Increasing knowledge concerning the indigenes of Africa, since the time when Shrubsall and those other authorities quoted by Biasutti wrote, has proved that our Bush-Hottentot population is composed of two distinct racial elements, namely: the Bush type (which is probably identical with the genuine Pygmy) and the Boskop type (which preceded the Bush type in our cave shelters but mingled with the Bush type to form the peoples of the Bushmen and Hottentot culture found in modern times). It is this pre-Bush or *Boskop* human type which, since Fritsch (1872) first committed the error on entirely inadequate evidence, various observers have been trying to saddle quite unjustifiably with his unsatisfactory terminological label "Hottentot" borrowed from cultural anthropology (Dart, 1937 *b*).

Both of these non-Negro but southern African—and, if we wish to retain that nebulous terminology, "negroid"—physical types are prognathic to a certain degree and are definitely chamaecephalic or low-headed; both have persisted until the present day; both are found (Orford and Wells, 1936) amongst the living Bantu in South Africa; both contribute in approximately equivalent ratios to the constitution of our living Southern Bushmen in the Union of South Africa (Dart, 1937 *b*). Boule and Vallois (1932) have shown the existence of the Boskop (or, as they still term it, "Hottentot") type in Pleistocene times from fossil remains discovered in a Nigerian, fluviatile gravel-bed on the southern side of the Sahara. Galloway (1937 *a*)

has displayed the Boskop features of the East African remains of early man discovered by Leakey.

It is not very strange therefore, to South African workers, that similar huge-headed but chamaecephalic and prognathic skulls should emerge in the population of Egypt and accompany the genuine Bush (or Pygmy) type there. The characteristics of the Boskop cranial type have been set forth by Galloway (1937 *b*); the outstanding divergences between the Bush and Boskop type in the living individual have been discovered in the head and the face of the living Bush population (Dart, 1937 *b*). Collectively, these studies permit a further inquiry into the data assembled from Egypt (see later description). To-day, amidst the bastardized product of Bush-Boskop admixture, interwoven with Brown, Armenoid and Mongolian elements, endless labour has been and still is required to unravel satisfactorily the tangled skein of human types consolidated in the modern Bush population of South Africa. But the outcome of such work, as has been done, proves that the pure Bush type is so similar to, that it cannot as yet be distinguished from the Pygmy type, *i.e.* the head is only 170–180 mm. in length, and, being narrow in relation to the length, its capacity is the smallest of all living types. *The microcephalic or dwarf-headed and low-vaulted Bush type cannot be confused with the ortho-ovoidal Negro.*

The presence of the Bush or Pygmy type in Egypt has been so repeatedly proved that question need not delay us. But the presence of Boskop Man there has not been envisaged. Relying on the observed facts concerning the Boskop type, I have made an analysis of the head lengths of all the skulls in the aforementioned Egyptian series used for the graph to determine the actual proportion of its presence there. I have therefore taken particular notice of those skulls having a head-length greater than 190 mm. It is significant too that these record lengths (beyond 200 mm.) are relatively more numerous in the earliest or Predynastic series. Table III provides an analysis of the data concerning these skulls of extravagant length in the Egyptian population over the entire range of time they represent. Unfortunately some of the skulls are so fragmentary that the breadth or height or both are not ascertainable. Consequently as in our graph, we take cognisance mathematically only of those which are sufficiently "complete" to provide all three measurements; but the total number of such skulls is given to the left of the table.

This table demonstrates that the Egyptian skulls having a length of 190 mm. or more form a select group of not less than 8·9 per cent. of the whole population. It shows, too, that they are ubiquitous, being present to a greater or lesser extent in every group at every period in time. Even in Woo's select series of the Ninth Dynasty (*loc. cit.*) there

TABLE III.

*Analysis of Egyptian Skulls of 190 mm. or more in Length.*

| | Period. | Total. | Incomplete. | | | Complete. | | | | | | Total. | Grand Total. | Per cent. of Grand Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Dolichocephalic. | | | Mesaticephalic. | | | | | |
| | | | ? | Dolicho. | Total. | Hypsi. | Ortho. | Chamae. | Hypsi. | Ortho. | Chamae. | | | |
| Derry | Badari and Mostagedda | **8** | 0 | 1 | 1 | 2 | 4 | 1 | 0 | 0 | 0 | 7 | 79 | 8·9 |
| Fouquet | El Amrah, etc. | **32** | 0 | 5 | 5 | 1 | 17 | 6 | 0 | 2 | 0 | 26 | 101 | 24·7 |
| Fawcett and Lee | Nagada | **43** | 5 | 12 | 17 | 5 | 13 | 7 | 0 | 1 | 0 | 26 | 314 | 8·2 |
| Thomson and Maciver | Early Predynastic | **12** | 1 | 4 | 5 | 0 | 3 | 3 | 0 | 0 | 0 | 6 | 89 | 6·7 |
| Thomson and Maciver | Late Predynastic | **32** | 1 | 7 | 8 | 0 | 12 | 7 | 0 | 2 | 3 | 24 | 231 | 10·4 |
| Motley | Dynasty 1 | 7 | 0 | 2 | 2 | 0 | 1 | 2 | 1 | 1 | 0 | 5 | 44 | 11·4 |
| Thomson and Maciver | Dynasty 1–5 | **24** | 0 | 2 | 2 | 0 | 13 | 4 | 0 | 3 | 2 | 22 | 197 | 11·2 |
| Woo | Dynasty 9 | **3** | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 3 | 69 | 4·3 |
| Thomson and Maciver | Dynasty 6–12 | **24** | 2 | 0 | 2 | 0 | 14 | 5 | 0 | 0 | 0 | 19 | 312 | 6·1 |
| Collett | Dynasty 12–13 | **32** | 1 | 14 | 15 | 0 | 9 | 8 | 0 | 0 | 0 | 17 | 177 | 9·6 |
| Thomson and Maciver | Dynasty 12–15 | **11** | 0 | 1 | 1 | 0 | 4 | 6 | 0 | 0 | 0 | 10 | 153 | 6·5 |
| Schmidt | Dynasty 18? | **17** | 1 | 1 | 2 | 1 | 6 | 7 | 0 | 1 | 0 | 15 | 167 | 8·9 |
| Thomson and Maciver | Dynasty 18 | **16** | 0 | 0 | 0 | 0 | 8 | 7 | 0 | 1 | 0 | 16 | 204 | 7·8 |
| Oetteking | Dynasty 18 | **5** | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 5 | 66 | 7·6 |
| Schmidt | Dynasty 18–21 | **24** | 0 | 0 | 0 | 0 | 9 | 14 | 0 | 1 | 0 | 24 | 250 | 9·6 |
| Thomson and Maciver | Dynasty 30–Ptolm. | **16** | 0 | 0 | 0 | 0 | 8 | 6 | 1 | 0 | 1 | 16 | 168 | 9·5 |
| Thomson and Maciver | Roman | **7** | 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 7 | 99 | 7·1 |
| Schmidt | Modern | **5** | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 5 | 141 | 3·5 |
| | **Total** . | **318** | 11 | 49 | 60 | 10 (3·2%) | 131 (52·6%) | 88 (34·9%) | 2 (·8%) | 12 (4·8%) | 7 (2·8%) | 253 (100%) | 2861 | 8·9 |

are three skulls of 190 mm. or over, and of these two are dolicho-orthocephals, and the other is a dolicho-chamaecephal. These exceedingly long-headed specimens maintain over the whole period an average distribution identical with that displayed in the earliest series exhumed at Badari and Mostagedda. They are most frequent in Fouquet's (*loc. cit.*) Predynastic series, and least frequent in Schmidt's modern series.

Of these 253 long-headed skulls, not a single one is brachycephalic; only twenty-one, or 8·4 per cent., are mesaticephalic; the vast majority, *i.e.* 229, or no less than 91·6 per cent., are dolichocephalic. We can therefore afford to neglect here any further discussion of these aberrant and scattered, but very long-headed *mesaticephals*; merely noting, in passing, that these monstrous hybrid forms are most frequent in the early dynastic era, when so much disturbance of the population took place concurrently with the first serious arrival of brachycephals.

But it is very material to the problems we are considering to analyse the preponderant group of excessively long-headed *dolichocephals*. We find that only ten of them (or 3·2 per cent. of the whole group) are hypsicephalic, and that of these significant types, the majority occur in early Predynastic times; thereafter, one emerges some 2000 years or more later in Oetteking's series of Dynasty Eighteen, and another about 5000 years later in Schmidt's modern series, lonely, unwitting, but outstanding, heralds of a great bygone event. They are the longest-headed of those *Nordic* dolichocephalic hypsicephals to whom I have already referred.

The bulk of these outrageously long skulls are orthocephalic; this set accounts for no fewer than 131, or 52·6 per cent. of the whole dolichocephalic group. From this it might be assumed that the type from which all these striking forms derive, was of this orthocephalic category. If that were so, the type would be one new to science, corresponding with no known racial type; but no such novel idea is necessary, for, if we turn to the last or chamaecephalic division of prodigiously long dolichocephals, the explanation becomes obvious.

These individuals, present like their hybrid orthocephalic relatives in every group down to the most recent, now rising and now falling, but never ceasing, like some persistent undertone in a gigantic theme, are the purest representatives of the Egyptian *Boskop* population. Their eighty-eight examples constitute 34·9 per cent. of the extraordinary group of long-heads we are discussing. These long-headed, low-vaulted, Boskop types—whose ancestral remnants have been recovered from prehistoric palaeolithic deposits in Africa at points as remote from one another as Nigeria and the Transvaal, and who are neither Negro nor Bush—form an outstanding human group; whose living kith and kin are still found

to-day amidst Egyptian, Pygmy,* Bantu and Bush groups ranging geographically from the Mediterranean Sea to the Cape of Good Hope, fossilized as it were in our midst. Boskop man is the most ancient known type of living sapient man.

For the sake of regularity and comparison the chief features of these two important physical types—whose imperfect isolation has led unwittingly to such confusion—are here briefly summarized: The *Bush race* are pygmoid in stature (135–145 cm.) and slender in build like the Brown race, but are if anything more stockish in type. Their deep copper-brown bodies are virtually hairless; even their heads being only partially covered with small, tightly rolled and discretely dispersed, peppercorn hair distributed like a small skull-cap on the head. The iris is dark brown and the conjunctiva a dirty white. The skull is short (170–180 mm.), but is none the less relatively narrow (dolichocephalic), of low height (chamaecephalic), and acutely pentagonoidal (or coffin-shaped) when viewed from above, and of small capacity (microcephalic); it is *foetal* in form. Eyebrow ridges are completely lacking, and the narrow forehead, instead of sloping backwards or rising vertically, bulges anteriorly as it rises towards the crown of the head, and then falls away abruptly to the prominent occiput posteriorly. The horizontal orbits are small and circular, widely separated, and have very thin margins; the cheeks are wide and their bony supports prominent, giving the short (chamaecephalic) face a smoothly pentagonoid (or, as others describe it, triangular) form, widest at the zygomata, and falling away to a point in the chin area. The face is almost vertical in profile, the nose being short, broad and low, and the oral region shapely and not pursed; although broad-lipped and convex in form, it is not

* Since presenting this paper I have received P. Schebesta's exhaustive study, Die Bambuti-Pygmäen vom Ituri, Bruxelles, 1938, where he makes the following generous statements:—

"Dart's grosses Verdienst für die Buschmann-Forschung liegt darin, dass er die Rassenkomponenten, aus denen sich die Buschmänner zusammensetzen, auf Grund von Beobachtungen und Messungen an Lebenden und an Skeletten aufzeigt und beschreibt. Dass die Buschmänner eine heterogene Rasse sein müssen war jedem Einsichtigen klar. . . . Dart's Studie bedeutet darum einen grossen Fortschritt in der Buschmannforschung und sie zeigt auch, wie mir scheint, die Lösung des Buschmannproblems auf; vor allem klärt sie die scheinbaren Widersprüche früherer Forscher. . . . Die Resultate, die Dart aus seinen Untersuchungen zieht und denen ich meine weitgehende Zustimmung gebe, sind: Die Buschmänner setzen sich aus zwei gleichwertigen Rassekomponenten zusammen, der Busch- und der Boskoprasse, den andere, wenig bedeutende Rassenelemente überlagert sind. Die Buschrasse ist mit der Bambutirasse (ihrer Haupkomponente) identisch. Aber auch in der Bambutirasse ist der Boskoptypus vertreten, allerdings ungleich schwächer als im Buschmann. . . . Damit ware der Zusammenhang zwischen Bambuti und Buschmännern geklärt. Dart's Forschungen ermöglichten es mir, meine bisherigen Vermutungen über die Zusammensetzung der Buschmänner zu konkretisieren."

sufficiently prognathic to be protruded beyond the nose; the pentagonoid form in facial view and the vertical profile are emphasized by an inflated infraorbital region. The lips are full but shapely, the lower jaw small and vertical in profile, the ears small, square, and non-lobulated and closely attached to the head. The face as a whole is of *pygmoid* or *foetal* type corresponding with the foetal form of the cranial bones. The child-like body is incompletely erect, and consequently the buttocks protrude posteriorly, giving a false appearance of *pancake* excessiveness to the baby-like distribution of the subcutaneous fatty deposits there. The genitalia and the tiny hands and feet share with the remainder of the body in the paedomorphic structure of these infants of the human race.

The *Boskop race* * have a somewhat taller stature (150–160 cm.), and are more stockish or sthenic in build. Their dark reddish-brown bodies are also virtually hairless, but their heads are better, but still sparsely covered with more coarsely-rolled peppercorn hair distributed like a skull-cap with a frontal prolongation upon the elongated, frequently trigonocephalic head. The iris is blackish-brown and the conjunctiva a brownish-white. The skull is very long (190–200 mm. or more), but is relatively narrow (dolichocephalic), acutely pentagonoidal (trigonocephalic) when viewed from above and of tremendous capacity (macrocephalic); although massive, it too is foetal in form. Eyebrow ridges are definitely present, but are not salient, and the relatively narrow and somewhat retreating forehead rises abruptly but to no great height, and turning back rather abruptly follows a slowly rising (almost horizontal) contour backward on to the parietal bones, and then falls away with a rapid slope to the extremely prominent occiput. The wide and low rectangular orbits are massively constructed, and prominent due to their own breadth and their own very wide separation below the small forehead; hence the external orbital processes are definite and the cheek-bones outstanding. The rugged face is chamaeprosopic and acutely pentagonoid; it is prognathous in profile. The nose is fairly long but very broad and relatively elevated owing to the full but not inflated infraorbital region; the oral region is convex, muzzle-like and protruded beyond the nose, its gauntness being emphasized by the bony excavation of the underlying maxilla and the seeming inadequacy of the soft parts to cover the expanded alveolar region. The mouth is large, wide and strongly pursed; the lips are wide, flaccid and horizontally furrowed, and the massive lower jaw has a receding profile. The ears are non-lobulated but are pyriform, being expanded above, and they stand well away from the head. The face as a whole is of a *chimpanzoid* or

* See my recent paper, "Fundamental Human Facial Types in Africa," in S. Afr. Journ. Sci., vol. 35, for pictorial representations of this and the other facial types discussed above.

*muzzle-like* character. The body is still less erect than that of the Bush type, and the buttocks are so protruded as to assume an *angulated* form. The genitalia are not so markedly infantile as, and the hands are more coarse and massive than, those of the Bush type. As a whole the Boskop human type may be summed up paradoxically as a *gerontomorphic paedomorph*—a precocious attempt on the part of Nature to produce a giant form from a foetal type. The Neanderthaloid affinities of these two human types have received attention in numerous papers from this school. Their infantile speech corresponding with their primitive culture has been displayed by Maingard (1938).

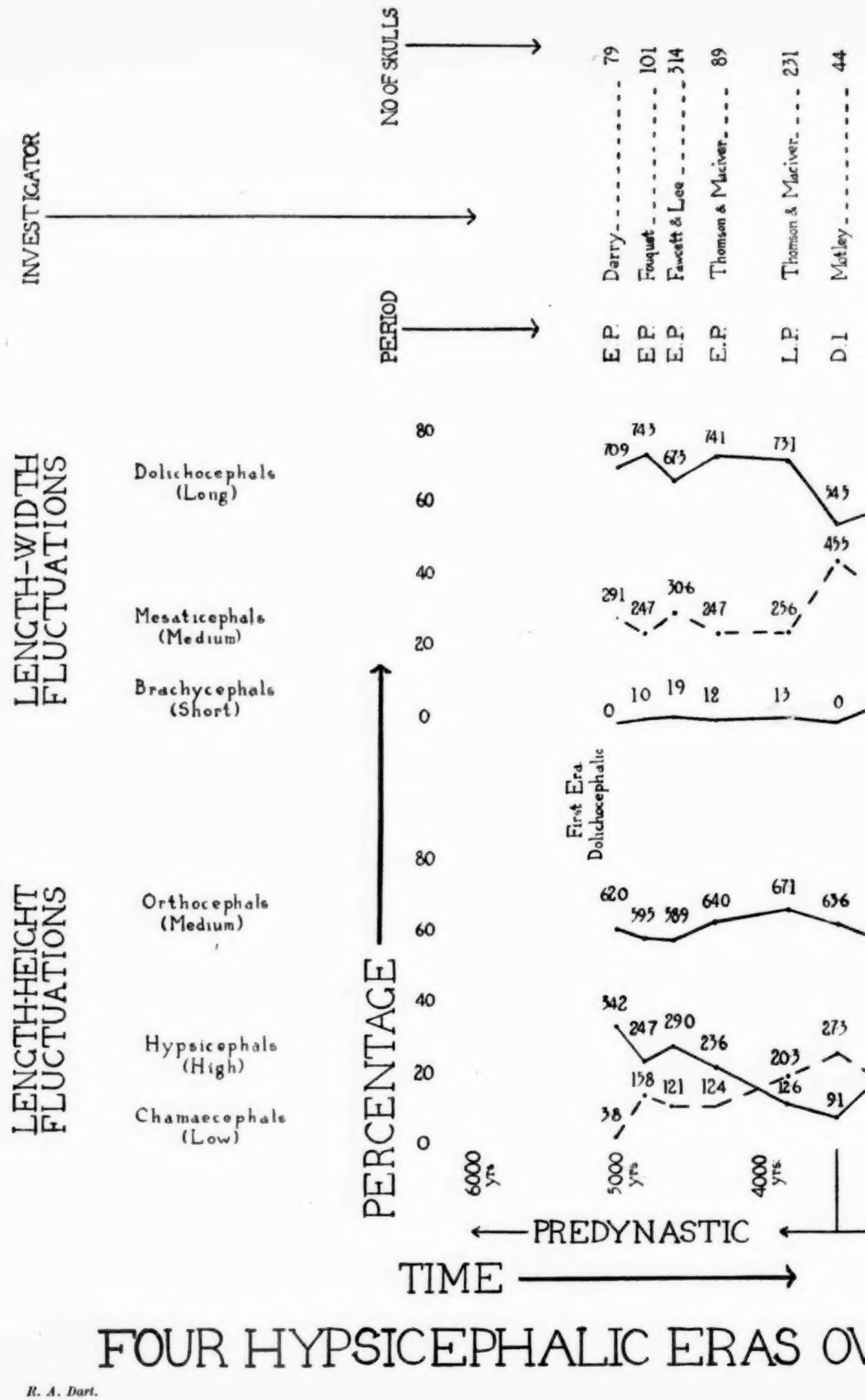
From our analysis it has emerged that in Egypt, from the earliest known period, two low-vaulted human races—the macrocephalic Boskop and the microcephalic Bush, both of which are dolichocephalic—have been contesting with two high-vaulted races—the macrocephalic Nordic, which is dolichocephalic, and secondly the macrocephalic Armenoid, which is brachycephalic—for representation and, as opportunity favoured, for relative dominance amidst a mesocephalic Brown population, which also combined dolichocephaly with its orthocephaly. It is to this predominantly orthocephalic race as well as to the direct hybridization of low-vaulted with high-vaulted cranial types that we owe the greater percentage of orthocephalic skulls (found interposed between the extremely high and the extremely low specimens) of inordinate skull-length discovered down the ages in Egypt.

Save for a few isolated brachycephals, whose physical features have been described by Elliot Smith (1923 and 1934), these are the four essential ethnic types with which we have to deal in Predynastic Egypt.

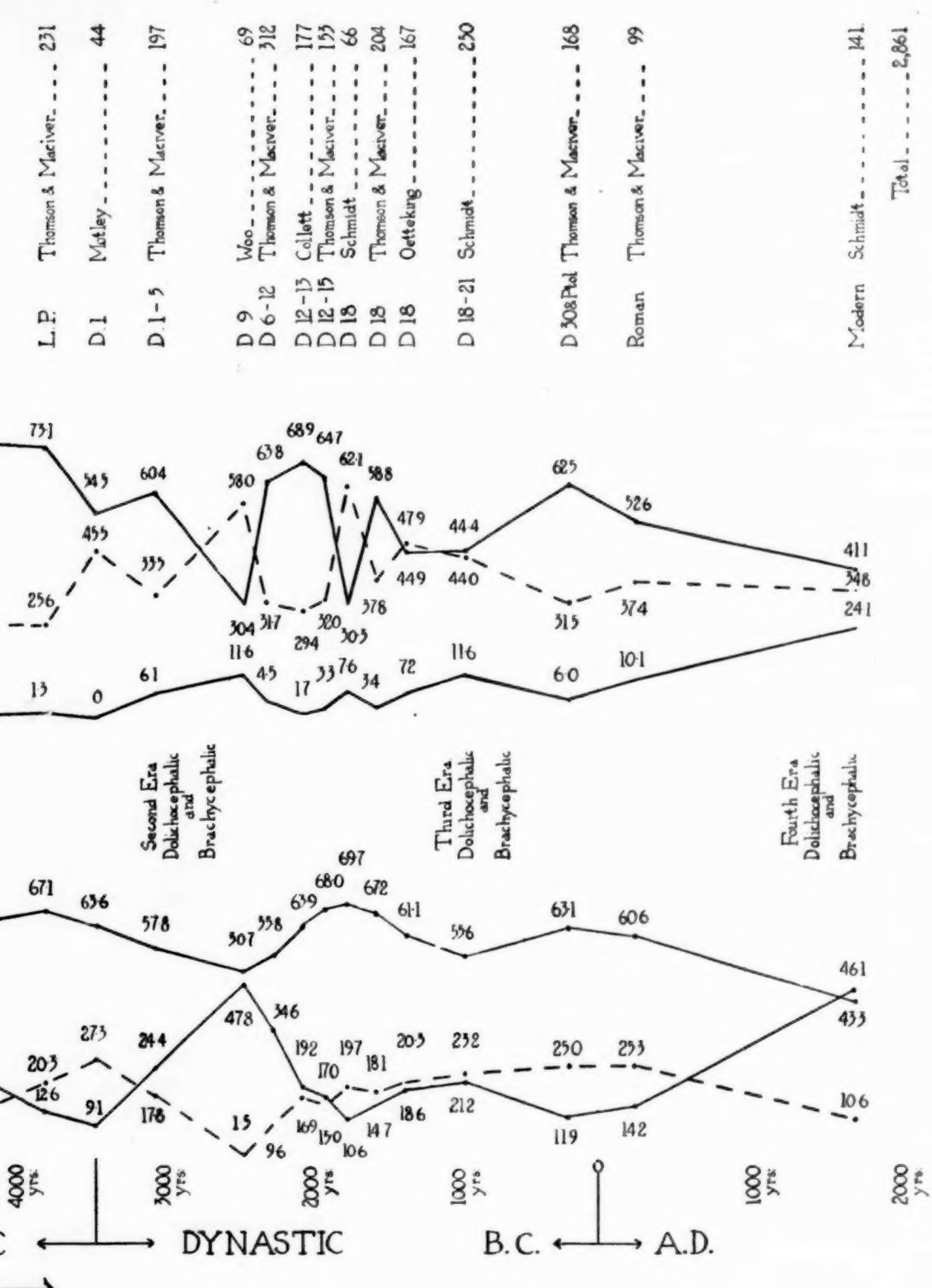
## 5. Bush and Boskop Wanderings beyond Africa.

The discussion of chamaecephaly in Egypt has thus led us firstly to the recognition of the essential and dual nature of these "austro-african and dwarf-headed" elements in the heterogeneous population of Ancient Egypt, which Biasutti so accurately recognized over thirty years ago. The examination has also served to reinforce and extend my recent conclusion, reached in ignorance of Biasutti's pioneer work, and founded on entirely distinct and separate data—that the Bush race was at one time distributed from the extreme south of the African continent to the Red Sea, by proving that the Bush race was accompanied by, or more probably preceded by, the Boskop race in its distribution to the most northerly part of Africa.

I do not attempt to discuss here *in extenso* the application of these novel facts towards the solution of the ethnographic problems of Europe




FOUR HYPSICEPHALIC ERAS OV




AS OVER 7000 YEARS IN EGYPT

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and Asia; but certain relevant issues must be noted if the earliest accessible population of Egypt is to be understood. It is obvious in the first place that, when these microcephalic Bush and macrocephalic Boskop elements were playing so considerable a part in the *chamaecephalization* of the Egyptian population, their influence could not have been confined to this restricted geographical area. Those elements, fused with and incorporated in the Brown race on the Mediterranean littoral, must have permeated beyond its borders wherever the navigating Egyptians penetrated in historical times independently of any still more ancient northward migrations of these same chamaecephalic African peoples themselves.

The amazing discovery—of three microcephalic crania and three femora belonging to Neolithic individuals of pygmoid stature in Switzerland by Kollman—towards the end of last century (*vide* Sergi, 1908) was unfortunately given short shrift at the distinguished hands of Virchow and Schmidt, who had the temerity at the time to deny the existence of pygmies, not only in Europe but in all other regions of the globe. Recognizing the ethnic significance of these few remains, Sergi (*loc. cit.*), on the other hand, applied Kollman's diagnostic touchstones of microcephaly and pygmoid stature in the study of the ancient Italian skeletons found in the province of Benevento, and shortly afterwards to the examination of Russian remains of the Early Iron Age from the Kurgans. The result was that, when he wrote his article on "Microcephalics and the Pygmies of Europe" in 1893, he had discovered no less than 47 skulls of this type in the Mediterranean basin and 145 in Russia, *i.e.* 192 in all. The average capacity of these skulls, both male and female, in the Mediterranean area was 1137·7 c.c. and those in Russia 1141 c.c. The study of the characteristic forms of the skulls and their correlation with stature, convinced him of the inherent truth of Kollman's contention, that there existed in ancient Europe a widespread human stirp of small stature and small cerebral capacity. Further information about the dispersal of this human type in Sicily, Sardinia, Sannio and Orvieto is discussed in his later work on Italy (Sergi, 1919).

The penetration of such a microcephalic dwarfish race, described by Sergi as one of the early Mediterranean stocks, into Europe is now generally admitted for, as Keane (*op. cit.*, p. 461) states:

> Their presence in Sardinia has now been determined by A. Niceforo and E. A. Onnis, who find that of about 130 skulls from old graves thirty-five have a capacity of only 1150 c.c. or under, while several living persons range in height from 4 ft. 2 in. to 4 ft. 11 in. Niceforo agrees with Sergi in bringing this dwarfish race also from North Africa.

Sergi (1907) assembled the series gathered by Niceforo with those collected by Ardu, Zanetti and himself in the Sardinian population and thoroughly examined the distribution of small stature, small heads, prognathism

and colour there to-day. It is therefore unnecessary for me to discuss the penetration of the Bush type into Europe any further; but in this connection we may recall that Fleure and James (1916) discovered, as far away as Wales, amidst the living population:

> A Mediterranean type with reminiscences of negroid character, perhaps suggesting links with the Palaeolithic negroids described by Verneau from the Grottes de Grimaldi. This type is rather small, shows marked dolichocephaly, often without large measurements, has dark eyes, black hair, which is closely curled, a rather broad nose, and short stature. We have met only the slightest traces of this type, and think it wise to do no more than mention it at the present stage (Plate IV, 6).

But the immigration into Europe of African racial forms and their hybridization there with European types was not confined to these microcephalic (or Bush) types in Neolithic times. The outstanding and classical human type of the Late Palaeolithic period is the old man of Cro-Magnon, which has been accepted by most anthropologists who follow the French school of thought (*e.g.* Boule, 1923) as a genuine racial type—one which:

> may be considered as a racial type, around which there may gravitate variations, due probably to the influence of varying geographical environments, and perhaps also to racial intermixture. But as a whole they really form one stock, a fine race, which, as de Quatrefages has said, played an important part over a considerable period of time.
>
> This race did not come to an end in France with the termination of Quaternary times. As we shall see later, it not only survived during the Neolithic Age, but, even in our own day, it still appears sporadically in different parts of France, especially, according to Dr. Collignon, in the Dordogne (fig. 188). M. Verneau has been able to trace the Cro-Magnon race throughout Spain; it is found in burials, dating from more and more recent times the further one travels southwards (*op. cit.*, p. 288).

The length of the Cro-Magnon skull is 202 mm.; it is dolichocephalic and, according to Sergi (1908) and all other observers, chamaecephalic; it is obtusely pentagonal (*i.e.* foetal) in form; its zygomatic processes are so wide that, despite the elevation and elongation of the nose, the face is disharmonic with the skull and is low or, at most, of medium height in relation to the great width. The upper jaw displays alveolar prognathism and the orbits are low and wide, disharmonic with the leptorrhine nose. Sergi refused to accept its pentagonal form as that of a racial type, but regarded it as a chance form characterized by the persistence of foetal and infantile characteristics such as he frequently encountered in European Neolithic and Recent skulls. He showed that the vast majority of skulls of similar great age now available in Europe display *chiefly ellipsoidal* and more rarely ovoid forms of skulls (*loc. cit.*).

In terms of our analysis of the Egyptian population, *the Cro-Magnon*

*specimen has all the earmarks of a Boskopoid individual*: who emerged from the bastardization of the hypsicephalic, leptoproscopic, leptorrhine and *ellipsoidal Nordic* race, with the chamaecephalic, chamaeprosopic, platyrrhine and *pentagonoidal Boskop* race. The same type of bastardization characterized the "Mesolithic" inhabitants of Morbihan in France (*vide* Péquart, Boule and Vallois, 1937). Sollas, Boule and many other writers in common with Biasutti have constantly reminded us that the steatopygous sculptures of the Late Palaeolithic period in Southern Europe resemble Bush-Hottentot women; Obermaier, Breuil, Peringuey and others have asserted that the Aurignacian types of industries throughout Africa and in Europe are similar, and, summing up their views, Boule (*op. cit.*, p. 312) says: "We are led to admit that they (the first Aurignacians) are African in origin." It would be strange if the culture were African and some of the coeval skulls were not.

Chamaecephaly persists in a small percentage of Europeans so different from the microcephalous group that, when he encountered the type in Sardinia, Sergi (1919) divided the specimens into two groups, *Ellipsoides lateriforme* and *Ellipsoides cilindroide*. There is no doubt from the pictures of these two so-called "ellipsoidal" types, from their excessive length of 199 to 207 mm., increased endocranial capacity and chamaecephaly that these too are Boskopoid forms; though they betray, as does Cro-Magnon man, hybridization in their ellipsoidy and leptoprosopy. He therefore rightly contrasts these hybrid skulls, the most striking of which dates back to the "eneolithic" period, with his *Ellipsoides pelasgicus* form, "*il quale é molto dolichocefalo ma é cranio di grande altezza, ipsicefalo con lati paralleli.*" Therefore, as he rightly says, it has nothing whatever to do with the *pelasgic ellipsoid* type. This latter type is no other than our dolichocephalic hypsicephal; the macrocephalic type of the Nordic race; the most frequent and characteristic type of skull in Neolithic Europe; the type of Brünn, Galley Hill and Chancelade, and the "long barrows" of the British Isles; the type which is represented in Egypt in Early Predynastic times. It is also the Egyptian Pharaonic type for, while he had no opportunity of verifying whether the mummy of Rameses II had a skull of the pelasgic ellipsoidal form, Sergi (1908, pp. 234–235) displays the head and face of the mummy to show that Pharaoh must have had the elongated and narrow face of this *pelasgic ellipsoidal or Nordic* type. It is found in earlier times in Pepi I and other kings of Egypt.

Out of 354 Ancient European skulls listed by Sergi—of the Ancient Bronze and Iron periods of Sweden, the Neolithic and "Cairns of Arran" in the British Isles, and the Neolithic of France, Switzerland, Spain, Sardinia, Italy and Sicily—318 (or 89·8 per cent.) belong to the dolichomorphic group, and only 36 (or 10·2 per cent.) to the brachymorphic group. Out

of these 318 dolichomorphs no less than 179 (or 50·6 per cent.) are *Ellipsoids*, while 96 (or 30·2 per cent.) are *Ovoids*, and 43 (or 12·1 per cent.) are *Pentagonoids*. The ellipsoid skull throughout these periods is unquestionably the most frequent; it is the type skull of the Nordic race. The relatively short, obtuse pentagonoid, I follow Elliot Smith in regarding as the type of the Brown race (Dart, 1937 *a*). The ovoid skull in Europe is not negroid, but is probably a hybrid form between these two basic (ellipsoid and obtuse pentagonoid) types, assisted perhaps by the slight brachymorphic hybridization.

Of eleven skulls coming from Upper Palaeolithic deposits in Europe, Sergi (1908, p. 228) determined that eight were *Ellipsoids* and three *Ovoids*, while Cro-Magnon man is a more *acute or fœtal* type of *Pentagonoid*. These data show that these characteristic types were present in the most ancient communities of *H. Sapiens* in Europe; that the ellipsoid type is the commonest and most widespread from England to the northern frontier of Italy, and from Spain to Bohemia; and that Boskop types, if ever present in Europe in great numbers, were already growing relatively rare in Late Palaeolithic times in certain parts.

The chamaecephalic dolichocephaly found in Cro-Magnon man recurs in the long-headed skulls of Olmo (200 mm.) and Castenoldo (189 mm. and 202 mm. respectively) found at Alfedena in Italy. They display cranial contours, cranial arc heights, and indices of strictly comparable character (Sergi, 1919), and in these respects recapitulate those of the Boskop man. Further, the admittedly racially mixed (so-called ? negroid), adult, Late Palaeolithic skeletons of the Ligurian coast north of the Mediterranean, excavated by the order of the Prince of Monaco, fluctuate from 190 to 211 mm. in length, and though of moderate height have the acute pentagonal form, extremely wide zygomata, wide rectangular orbits and chamaeprosopic faces with alveolar prognathism, such as characterize the Boskop type.

On the opposite Algerian coast at Afalou and Mechta-el-Arbi, west of Tunis, numerous palaeolithic skeletons have been discovered (Arambourg *and others*, 1934), whose close relationship with one another and with the specimens from Cro-Magnon, the Ligurian coast, Predmost and Obercassel have been demonstrated by these authors. "En somme, lorsqu'on établit une comparaison entre le type qui prédomine d'Afaloü et les autres fossiles d'Europe, d'Asie ou d'Afrique, c'est toujours vers la race de Cro-Magnon qu'on est ramené" (*op. cit.*, p. 266). In other words, the proper interpretation of the Cro-Magnon hybrids is the key to understanding the Late Palaeolithic population of the Old World.

In the Kurgan burials of southern Russia a large number of skulls were exhumed, ranging from the Neolithic to the Iron Age in time. Sergi

(1908) catalogued 1567 of these skulls, and found that 598 (or 56·13 per cent.) were, as he terms it, Eurafrican in type, while 469 or (43·94 per cent.) were Eurasiatic. Of the Eurafrican group no less than 359, or 60 per cent., were *Ellipsoids*, while 103 (or 17·2 per cent.) were *Ovoids*, and 136 (or 22·8 per cent.) were *Pentagonoids*. He published (*loc. cit.*) the measurements and indices of 92 so-called Eurafrican specimens, and I have examined the 90 "complete" ones in the same manner as the Egyptian series.

The distribution is as follows:—

| | Hypsi. | Ortho. | Chamae. | Total. | Per Cent. |
|---|---|---|---|---|---|
| Dolicho . . | 14 | 24 | 7 | 45 | 50·0 |
| Mesatic . . | 19 | 21 | 2 | 42 | 46·7 |
| Brachy . . | 3 | 0 | 0 | 3 | 3·3 |
| Total . . | 36 | 45 | 9 | 90 | .. |
| Per cent. . | 40·0 | 50·0 | 10·0 | .. | 100·0 |

Hence one half of this Eurafrican sample in southern Russia was dolichocephalic and orthocephalic; 40 per cent. are hypsicephalic, and 10 per cent. chamaecephalic. Amongst these individuals no less than 30, or one-third of the group, had a cranial length of 190 mm. or more. Of these excessively long-headed types 22 (or 73·3 per cent.) were dolichocephalic, and the other 8 (or 26·7 per cent.) were mesaticephalic. While 5 (or 16·7 per cent.) of them were Nordic hypsicephals, 18 (or 60·0 per cent.) were hybrid orthocephals, and 7 (23·3 per cent.) were chamaecephals, or genuine Boskop types so far as their cranial boxes are concerned. Similar very long-headed individuals with prominent zygomata, prognathism and other stigmata of the Boskop type occur in North Wales (Fleure and James, *op. cit.*, pp. 113–115).

There is no further need for me to multiply instances in order to demonstrate the conspicuous and primary place of Boskop man in the story of sapient man in Europe and Asia as well as in Africa. Dixon (*loc. cit.*) traces his Proto-Australoid (D-C-P) element through Spain, France, Mecklenburg, Denmark, Siberia and Bohemia to Sweden. The extent of the Boskop influence outside Africa can be determined only by a re-analysis of all the relevant material designed for that particular objective, and is certainly outside the scope of this article, whose central issue is the racial history of Egypt. If we have been led to march across the confines of that crucial area, it has been done merely to display the success attendant upon the labour of those pioneers who have attempted, previously, to

attack the general problem of mankind from a wide but earlier perspective. The fact that so wide a distribution is claimed in Europe for the so-called "Cro-Magnon race," whose Boskop affinities we have discussed, is sufficient commentary at the present stage upon the broad dispersal of the Boskop type over the same area in Late Palaeolithic, Neolithic and Modern times in Europe.

### 6. The Rhythmicity of Human Movement into Egypt.

When we are confronted by population-phenomena as regularly fluctuant as those observed in Egypt it is but natural to seek their cause. However remote such inquiry may appear to be from physical anthropology, it must be made if our facts are to find meaning. Differences in head form have enabled us to outline the movement into and the incorporation within the Egyptian population of relatively vast numbers of alien northern peoples—principally of European (or Nordic) derivation—in four successive waves. What has been the driving force behind these repeated migrational activities? Either they were casual outbursts inspired by spontaneous whimsies of powerful groups of ambitious individuals accidentally emerging at fortuitous historical intervals; or, alternatively, cosmic events provoked these population movements from Europe as inevitable, recurrent responses.

Since Huntington first published "The Pulse of Asia" the coincidence of climatic disturbance and human movement has been seriously studied and the intimacy of the relationship between meteorological and population problems dimly appreciated. He attributes to climatic modifications, even those minor variations occurring within the period of historically recorded time, a preponderant influence in determining human movement from the north. If his concept is correct there is evidence of variations in climate since glacial times adequate to have caused very profound movements of northern peoples.

According to Croll's astronomical theory, the glacial periods were due to the fluctuation in position of the plane of the earth's equator relative to the plane of its elliptical orbit about the sun. The equatorial plane varies in such a way that, in an equinoctial precessional period (*i.e.* once every 21,000 years), summer occurs in the northern hemisphere while the earth is as remote as possible from the sun (*i.e.* in aphelion). This divergence in position, by producing short, hot summers and long, cold winters, is assumed to have been adequate to produce the periodical glacial phenomena displayed geologically.

That a majestic periodicity of some kind governs all climatic phenomena is little disputed; investigation is rather directed to discovering the nature and length of the periods involved. Superimposed on the annual seasonal

rhythm is an alternation of cold-damp periods averaging fifteen years in length and warm-dry periods averaging fourteen and a quarter years in length. Analysed by Brückner, these periods alternate regularly but vary in length; the cold-damp fluctuating from five to twenty-five years and the warm-dry ranging from ten to twenty-five years, during the two centuries from A.D. 1691 to 1909. To these "Brückner periods" Wright (1936) refers Hedström's moraine periods of sixteen and seventeen years duration, during the glacial retreat in Sweden and the comparable moraine of the Kerry mountains in S.W. Ireland linked by knobbed askers, each knob of which represents a year's glacial retreat.

In addition to these minor or short-period rhythms of Brückner, major undulant climatic phenomena have also characterized the retreat of the ice; they are evidenced by massive moraines on the northern side of the eastern Alps and also in Switzerland, which "fall into three important groups corresponding respectively to elevations of the snow-line of 300, 600 and 900 metres above the maximum of the Würm Ice Age or, what is the same thing, to depressions of 900, 600 and 300 metres below the present snow-line" (Wright, *loc. cit.*). They are respectively the Bühl, Gschnitz and Daun *retreat-stadia* of Penck, the first of which is dated 20,000 and the last as 7000 years ago.

The major or long-period, post-glacial rhythms of Penck are linked to the minor climatic alternations of Brückner by at least two series of undulations of *intermediate* character. Within the period of 7000 or 8000 years since the Daun stage the northern European climate was not stable. On the one hand it sustained large-scale variations such as influenced the whole vegetation; and botanists divide it into Boreal (7500–5500 B.C.), Atlantic (5500–2300 B.C.), Sub-Boreal (2300–700 B.C.) and Sub-Atlantic (700 B.C. onwards) epochs, climatic alternations varying roughly from 1500 to 3000 years in length. On the other hand, according to Wright (*op. cit.*, pp. 56–57), the "Brückner periodicity" of retreat characterizes only certain periods of 200–300 years and other equally long periods are without it; a similar short-scale alternation of periods with or without Brückner rings is observable in the growth rings of the big trees of California.

These lesser climatic fluctuations with a periodicity of several centuries were first analysed by Huntington (*loc. cit.*), who demonstrated from historical and other records that dry periods had occurred in Central Asia about A.D. 1200 and A.D. 400–600. Later on, evidence from Palestine and Syria confirmed him in these deductions and postulated another major dry climatic event about 1200 B.C. along with indications of similar minor periods in still earlier times and also about 800, 600 and 100 B.C. and A.D. 300–400. These initial inquiries received important corroboration through the analysis of the growth rings in redwood trees by Dr. Douglas,

who drew therefrom a climatic curve which gives "the only definite yard-stick by which to measure the climate of historic time," and "each marked change that has been definitely determined in Asia is also strongly marked in California, for the two regions lie in the same climatic zone. The dry period in the thirteenth century B.C. is particularly prominent." (Huntington, 1919.)

The major dry events of the thirteenth century A.D. (the Mongol invasional period) and the thirteenth century B.C. (the period of the "Peoples of the Sea") are separated by an interval (2500 years) recalling those large-scale fluctuations established by the botanists. Further, Antevs (1923), in noting that the post-glacial climatic amelioration reached its climax from 5500 to 2500 years ago and suggesting that there were two climaxes about 2000 years apart (i.e. *circa* 400 B.C. and 2400 B.C.), pointed out that "The long periods—of thousands of years—are of fundamental importance for correlation."

If Antevs is correct and there is superimposed on the "Huntingtonian rhythms" of centuries an "Antevsian rhythm" of climatic millennia, it is apparent that the effect of this *millennial* rhythm * upon population movement would be more cumulative than those due to the *decennial* rhythms of Brückner or the *centennial* rhythms of Huntington and only less formidable than those due to the *deci-millennial* rhythms found by Penck and those *vigenti-millennial* rhythms of the Ice Ages themselves. During favourable millennia populations would increase and during unfavourable millennia their pressure effects would be demonstrable in terms of movement. That something of this nature has in reality occurred at intervals of a couple of millennia has already been anticipated.

Fleure (1927) says: "Now a subject of great importance to man is that of the growth of population. There seem to have been several occasions on which great spurts occurred—that due to the development of steam machinery and transport is fast weakening at the present time; that apparently connected with large-scale organization of government and communications, culminating in Imperial Rome, was a previous phase; that probably linked with the spread of the horse as man's companion preceded this by rather more than two millennia; while that associated with the first rise of food production was about two or two and a half millennia earlier still. The bettering of climate after the Great Ice Age must have been an important factor in the increase that we are now considering, and it may be dated a few millennia before the invention of food production."

* Compare also the 800-year cycle of peace and disorder displayed by Dr. J. S. Lee in "The Periodic Recurrence of Internecine Wars in China," China J., March-April 1931, and the letter by Flinders Petrie on cyclical phenomena in *Nature*, 1938, vol. 142, p. 620.

Combining the concepts of Huntington, Antevs and Fleure, and assuming the present period to be part of the most recent or *fifth* favourable post-glacial interval in human history, the four most favourable preceding intervals probably occurred. in the millennia *circa* the birth of Christ; 2000 B.C.; 4000 B.C.; 6000 B.C.; and 8000 B.C., while the least favourable millennia were those *circa* A.D. 1000; 1000 B.C.; 3000 B.C.; 5000 B.C.; and 7000 B.C. The favourable millennia thus postulated coincide with those periods in Egypt when we have discovered dolichocephaly and orthocephaly were asserting themselves—*i.e.* when the mesaticephalized population was "settling down" and was being least disturbed by the influx of foreign elements—while the intervening millennia are those of maximum disturbance and migratory flux.

The degree of coincidence existing between the phenomena exhibited by our graph and the climatic fluctuations indicated from the available evidence can scarcely be fortuitous. Indeed, it is not doubted to-day either that great movements of sapient mankind have taken place nor that climatic factors have been a very potent factor in provoking such movements. What is novel from our data is that these major movements from the north-west have occurred with tolerable certitude *at approximately bi-millennial intervals* since the glacial period. The population distribution of Egypt thus becomes indirectly a *meteorological time-clock*, whose accuracy will increase proportionately to the number of future observations made. Meantime, whatever individual or personal factors may have been involved in historically recorded human movements, it is apparent that the combined effect of human factors has been negligible in comparison with those resulting from cosmic forces over which man has no control.

## 7. Racial Dominance in Egypt.

Egypt reveals in miniature a portion of Nature's grand experiment of racial mingling. From the anthropological facts we have been considering, some inferences follow relative to the questions of racial dominance and racial persistence.

It has been claimed by Baur, Fischer and Lenz (1931) from the investigations of Frets amongst Dutch families, of Schreiner amongst Norwegians, of Hilden amongst Finns, and of Bryn also amongst Norwegians that, "There can no longer be any doubt that the development of the shape of the skull is controlled by the Mendelian laws of inheritance. . . . Brachycephaly is dominant over mesocephaly, and mesocephaly is dominant over dolichocephaly. . . . The finest outcome of the before-mentioned researches with their demonstration of Mendelian inheritance in the shape of the skull is that they explain why after thousands of years

of mingling of races in Europe, and amongst the emigrant Europeans of other parts of the world, there has not been produced a population with an average shape of skull, but that instead we find everywhere to-day, as of old, dolichocephals, mesocephals and brachycephals."

The conclusions of these workers are supported by our study of the Egyptians in respect of the persistence of cranial types over long periods of time. Their conclusions apply not only to skulls in their length-breadth but also in their length-height relationships. Our figures also support the Mendelian conception of skull inheritance. The approximation of the population in early Predynastic times to the 75 per cent. dolichocephal; 25 per cent. mesaticephal ratio; the persistent search of the chamaecephalic element for a 25 per cent. representation in the population; and the presence of approximately the same percentage of hypsicephals over the entire series are mathematical data suggestive of the Mendelian explanation: but where so many genetic factors are present the mathematical reading of the study is not simple (*cf.* Dixon, *loc. cit.*).

We have isolated at least one brachycephalic, Armenoid, and at least four dolichocephalic, Bush, Boskop, Brown and Nordic types in this racial mixture of Egypt. The permutations and combinations possible through their varying length, width and height of skull are numerically very considerable. To attempt a solution of the human racial muddle in Egypt along Mendelian lines would involve us in mathematical reckonings outside our present scope. I may, however, draw attention, in addition to the preceding proportions, to another suggestive mathematical fact: that the 25 per cent. chamaecephals (or hypsicephals) aimed at, as the population "settles down," seems to contain a little over 6 per cent. (or approximately one quarter) of one recessive racial class, and three-quarters of the other (or least recessive) part of the recessive community. Thus the hypsicephalic brachycephals and the chamaecephalic Boskopoids form the least numerous of these several elements in the wide series; this phenomenon may also be of Mendelian character.

But in one important respect there is no support whatever for the conclusions arrived at in north-western Europe. Brachycephaly is not dominant over mesaticephaly, nor is mesaticephaly dominant over dolichocephaly in Egypt. There the position is reversed; dolichocephaly is dominant over mesaticephaly, and mesaticephaly is dominant over brachycephaly; moreover, orthocephaly is dominant over hypsicephaly and over chamaecephaly throughout the whole group. The analysis shows also that, left alone and given time, a high degree of hypsicephalization, whether brachycephalic or dolichocephalic, ultimately becomes recessive, not only to the dominant orthocephaly, but even to chamaecephaly as well.

We need not, on that account, suggest that the European investigators reached erroneous conclusions. I have already had occasion to point out that their conclusions do not hold true in a study of the Bush population of South Africa (Dart, 1937 *b*). The preponderance of dolichocephaly in the Bantu shows that the conclusions also fail to hit the mark in Negro Africa. In other words brachycephaly, if dominant to dolichocephaly, is dominant only to Nordic or European dolichocephaly; it is not dominant to Brown, Negro, Bush or Boskop dolichocephaly—the dolichocephaly of Africa; further hypsicephaly, both European and Asiatic, is recessive to African orthocephaly, both that of the Brown and that of the Negro race; it is recessive even to African chamaecephaly, both that of the Bush and that of the Boskop race.

## 8. Conclusion.

By a simple extension of Retzius's cephalic indicial method to the altitudinal index we have divided the Egyptian population into nine sub-groups and have shown that certain of these have validity as human races. Despite their common possession of the feature of dolichocephaly, we have been able to separate the hypsicephalic Nordic from the orthocephalic Brown; and to dissociate each of these from the chamaecephalic Bush and Boskop people. By their great cephalic length we have distinguished the Boskop from the Bush folk, and by their chamaecephaly we have divorced them from the Nordic people. Although both Nordic and Armenoid are hypsicephalic, the former is dolichocephalic while the latter is brachycephalic.

By means of a time-graph we have traced the percentage fluctuations in cranial indicial values over a period of 7000 years or more in the Nile Valley; and have deduced therefrom the minor and secondary part played by the Armenoid race, as compared with the major and primary rôle assumed by the Nordic race, in the history of Egypt. With the aid of varied data an attempt has been made to co-ordinate these wanderings of sapient man with the rhythmical climatic changes; which appear to have been in provocative progress ever since the last Ice Age, and whose earlier major Pleistocene fluctuations seem to be correlated with the evolution of human types of gradually increasing osseous and mental maturity.

Incidentally to this underlying theme, we have discussed the widespread presence of Boskop Man in Northern Africa and in Europe in Late Palaeolithic times and the penetration of the Bush type into the same area, as well as the presence of both these physical types in Egypt.

The dispersal of the Boskop type—whose Neanderthaloid affinities have been referred to—from Europe to the Cape suggests a Boskop phase succeeding the Neanderthal phase in the evolution of Sapient Man. Within

this territory of Boskop distribution there emerged the Bush, Brown and Nordic types of dolichocephaly, probably as "sports" from the dolichocephalic Proto-Boskop stock. The evolutionary changes leading to the origin of these races had already occurred when our story opens.

We have been able to demonstrate the widespread distribution of the Nordic race across the Sahara, Egypt and Mesopotamia, which provoked the population distribution found in Badarian Egypt and Pre-Sumerian Mesopotamia. We have traced into the Nordicized Fertile Crescent the slow-moving Armenoid brachycephals and have shown how all later occupations of Egypt have been Nordic rather than Armenoid, even when they came from an Asiatic direction.

The hybridization story in Europe and in Africa discloses the fact that the Nordic race is simultaneously the most adventurous and the most vulnerable biologically of all the races of mankind. Its "Heel of Achilles" lies in its racial submergence, wherever it has mingled its blood with that of the indigenous population. The genetic recessiveness of the white skin is known universally. These biological factors assist us in understanding the historically persistent and even fanatical resistance, principally by Nordic peoples, to racial admixture; and their innumerable, instinct-inspired contrivances (of a feudal, hieratical, ritual, aristocratical, social, political or legal order) wherever they may have penetrated in the past upon the earth's surface, to preserve their racial purity and resist by every means at their disposal their racial destiny of submergence and biological old age.

In conclusion I express my gratitude to Miss J. Richards and Mr. G. C. Shaw for their assistance with the diagrams and other portions of the work, and particularly to my wife for her aid in the tabular and bibliographic portion of the work.

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# A SOCIOLOGICAL SKETCH OF SOTHO DIET.*

(PUBLICATION OF THE SCHOOL OF AFRICAN STUDIES, UNIVERSITY OF CAPE TOWN.)

By E. H. Ashton.

(Communicated by I. Schapera.)

(Read May 18, 1938. Revised MS. received March 13, 1939.)

This sketch, which was originally written in response to an invitation from the Principal Medical Officer,† Basutoland, aims primarily at recording the actual quantities and kinds of food consumed over a certain period by a number of Sotho families whom I had the good fortune to be able to study at close quarters. But it goes further than that, and attempts to draw certain general conclusions regarding the diet of the group to which these families belong—the Highland BaSotho—and to a lesser extent that of the second great group in Basutoland, the Lowlanders. The conclusions regarding the latter are only tentative for the reason that conditions vary greatly between different areas and even between different groups in those areas. An adequate survey of Sotho diet would require considerably more time than I was able to devote to it, and to obtain the best results it should of course be undertaken by an expert or, better still, by a team of experts on the lines of the investigation at present being undertaken in Nyassaland. The facts presented in this sketch are accurate so far as they go—the only trouble is that they do not always go far enough. Half a loaf is better than no bread, and, as at the moment we know so little of the foods and the nutrition of the Southern Bantu, a sketch of this kind has at least a sort of scarcity value.

In connection with the subject of this sketch two explanations are called for. A really comprehensive account of diet should include, besides a description of foodstuffs, their preparation and consumption, some

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assessment of the nutritive value of the diet and a description of the economic organisation of the society dealt with. The first of these has not been done for the sufficient reason that the necessary analysis and correlation is an expert's job, for which I am not qualified. Fortunately, however, this omission need not be fatal, for the kinds of food eaten by the BaSotho have already been analysed (7, 3, 2). Specimens of wild plants eaten in the Mokhotlong District have also been analysed by the South African Institute for Medical Research, but the results have not yet been published. It should therefore be possible, even taking into account the variations in the values of foodstuffs due to differences of soil, climate, and methods of cooking, for those interested to make as reliable an estimate of the value of Sotho diet as is possible short of making a large scale survey. Available medical data relevant to the subject have been included in order to facilitate correlation.

With regard to the second point, diet is the end-point of the economic organisation of society (and is indeed its touchstone and measure of efficiency in so far as its function is—to use Malinowski's phrase—the satisfaction of the primary need for food). In other words, the standard of diet obtaining in any society is largely the product of its economic organisation, and this is particularly true of simple communities such as that of the BaSotho where food production and consumption is the most important part of the production and consumption of wealth. The salient features of Sotho economic organisation have accordingly been touched on in the introduction to this sketch, but for various reasons a full account has had to be omitted.

The data, upon which most of this sketch is based, were obtained in the course of a general sociological study * of the BaTlokoa (a sub-division of the BaSotho, who live in the mountainous district of Mokhotlong), from October 1935 to February 1936, and a few days in April. Practically the whole of this period I lived with the natives and occupied a hut in the Chief's village.

Work in connection with nutrition was at first handicapped by the suspicion as well as the close private life of the people. Eventually through taking my meals with one of the Chief's households, as one of the family, I succeeded in gaining their confidence and also in obtaining first-hand information about their life. Other families then soon thawed and willingly co-operated in the work. Several families allowed me to keep regular records of their meals, and the heads of two went so far as to keep for me records of their own as well as of their neighbours' meals. One of them continued to do this for two months after I left, and the other for eight. These records are not absolutely complete, but they are full enough to

* This was made possible through a grant given by the Rhodes Trustees, to whose generosity, not in this alone, I am greatly indebted.

give a good idea of what and how much the BaSotho eat, and it is hoped that they may even be sufficiently detailed to permit of proper dietetic analysis.

The information given by these records relates primarily to the Highlands. With regard to the Lowland areas, where conditions differ somewhat, my information is not so detailed, but is, I think, sufficient to permit comparison. It is based on cross-checked, independent statements of BaSotho from different parts of the country, on a brief account of Sotho diet and health written for me through my father by Dr. Vollet, Medical Officer, Quthing, in 1935, and on my slight personal knowledge of the country. Two months' field work in the Mohales Hoek area in the winter of 1934 gave me a nodding acquaintance with the intermediate position created where Highlands and Lowlands meet.

## TOPOGRAPHY.

Basutoland is a small country of less than 12,000 square miles—much the same size as Belgium—lying in the heart of South Africa, between the three provinces of Natal, the Orange Free State, and the Cape Province. It has a population of over 600,000, including absentees. The 1936 census gives the following figures:—

| Population. | Males. | Females. | Total. |
|---|---|---|---|
| Enumerated . . . . | 238,705 | 320,568 | 559,273 |
| Absent at labour centres . | 78,604 | 22,669 | 101,273 |
| Total . | 317,309 | 343,237 | 660,546 |

It is clearly divided into two geological areas (4, 5), commonly known as the Highlands (the *Maloti*) and the Lowlands (the *Lesotho*). The Highlands occupy about three-quarters of its area, and the Lowlands a quarter. Most of the population is concentrated in the Lowlands, where it is probably one of the densest of Southern Africa (at least 102 per square mile, and probably considerably more).

This division is of human as well as of geographical significance, for each area has its own type of organisation with clearly marked economic differences. The Lowlands, which were once both pastoral and agricultural, are now almost entirely agricultural, 25 per cent. of its area being under cultivation. There the soil is on the whole good, although sheet and gully erosion and continued use for nearly a century without compensation in the form of fertiliser have in some parts reduced its fertility. (Manure

is used for fuel and other domestic purposes, and the use of chemical fertilisers such as superphosphates is inconsiderable, though slowly increasing. In the Agricultural Report for 1936, 820 bags are given for 1935–36.) Extensive anti-erosion and reclamation works are now repairing the damage caused by overstocking and careless farming, and remarkable results have already been achieved. The Highlands, on the other hand, which have magnificent grazing areas (5), are predominantly pastoral, and contain the greater part of the country's stock. Five per cent. of its area is, however, devoted to agriculture.

The country on the whole is well watered and the climate healthy. The average annual rainfall is about 30 inches in the Lowlands, and somewhat more in the Highlands, including the not inconsiderable precipitation which occurs in the form of snow. The range in temperatures in both Lowlands and Highlands is wide, though the temperature of the Highlands is considerably cooler; at Maseru over seven years it varied from an average maximum of 85·2 in December to an average minimum of 28·1 in July, while in the high mountain areas it varied from a maximum of 60 to a minimum of 11 for the same months.

The BaSotho belong to the southern cluster of the Sotho group of South Africa, and are liberally mixed with alien peoples, notably Natal and Cape Ngoni. They are by tradition and inclination a pastoral rather than an agricultural people. They have little affection, as a whole, for their lands, but have a sentimental regard for their flocks and herds. Circumstances, which are described later, are now compelling them to pay more attention to their fields and to improved methods of cultivation than heretofore, and also encouraging them to take a more practical view of their stock than they did. There are no secondary industries in the country, and trade is mainly in the hands of Europeans and other non-Bantu. Annually thousands of men (and as shown in the census returns women too) leave the country to seek work in the Union. The men work mainly on the gold mines, though a small proportion work on European-owned farms. The earnings of these emigrants contribute considerably to the maintenance of the people at home, and their absence of course relieves the pressure on the home food supplies. The general effect of this emigration on food production is discussed below.

Compared with other native areas in Southern Africa, Basutoland may be said to be fairly wealthy and prosperous. Its present stock population consists of 418,921 cattle, 1,695,325 sheep and goats, and 108,851 equines (1937 stock census), and is slowly increasing for the first time since the decline, which set in about 1931 (when small stock numbered 3,834,000 —there was no census of cattle), was greatly accentuated by the disastrous drought of 1932–33. The country is at present understocked, and though

further increase would be welcomed without detriment to the pastures, a watch is being kept by the administration to prevent the overstocking which previously occurred. The BaSotho are being actively encouraged to go in for quality rather than mere quantity, and at the same time experiments are being conducted with regard to pasture management to secure the greatest benefit from the mountain pastures. (For further details see the recent reports of the Department of Agriculture, Annual Reports, and Staples' Ecological Survey.)

The cattle of the BaSotho are of very mixed origin. They are tough and wiry and very valuable for draught purposes. In the eastern areas particularly, heavy slaughter cattle are also produced. Such is the internal demand for cattle that there is comparatively little export, and their chief value to the country lies in their domestic use—as a source of food and their draught power—rather than in their trade value as an exportable commodity. (Unlike the Bechuanaland Protectorate, which depends very largely on its cattle export, Basutoland sends out very few cattle. Of these some are exported as slaughter stock, the rest as trek oxen are exchanged with border farmers for young animals.)

It is estimated that there are only 26,829 taxpayers owning cattle. It is exceedingly difficult to say from this estimate what proportion of families (household groups) own cattle, for the term "owner" is vague and may include not only the head of a polygynous family as the single "owner" of the cattle belonging to the various households composing the family group, but also regard a man as the owner of the stock of, say, his widowed mother's household or of his brothers' widows, whose sons are not of age and for whom he is acting as guardian, and possibly even that of his absentee sons and brothers, whose affairs he is looking after. The number of households possessing cattle can therefore only be guessed at, but at a most favourable estimate, it is unlikely to be more than about 40 per cent. This figure does not, however, necessarily represent the effective distribution of cattle, *i.e.* their availability to the people for milk, ploughing, etc. For, on the one hand, some people have the usufruct of cattle though they may own none (under what is known as the *mafisa* system wealthy people give their friends and poorer relations some stock to look after and allow them to make full use of them except to slaughter or to sell. The number of such holders is not recorded, and as the BaSotho, according to the Director of Agriculture, have no hesitation in giving the census enumerators the name of the true owner, the holders are not even inadvertently recorded as "owners"). On the other hand, owing to the concentration of cattle and other stock in the Highlands, their availability to their owners, who live in the Lowlands, is limited, particularly as a source of milk, and to a lesser extent for ploughing.

Small stock in Basutoland consist almost entirely of sheep and goats, in the proportion roughly of three to one. There are various kinds of sheep, of which the most important is the pure bred merino, followed at some distance by bastard Persian. The latter produce a little wool of inferior quality, and are chiefly used for food; some people prefer to keep them rather than merino, because their meat is better and fatter, and they have a reputation for greater hardiness. The chief value of merino sheep is of course their wool, and for the last few years the Administration has been conducting a vigorous campaign to improve this asset by eliminating the bastard strains and introducing high-grade merino rams. All non-merino rams have now been castrated and stud merino rams are being distributed throughout the country at subsidised prices. At the same time improvements are being effected in the methods of shearing, classifying and marketing the wool, so that the maximum benefit from the production of their undeniably high-grade wool may be obtained. Though some of these schemes have only been going for 3–4 years, the reputation of Basutoland wool has already improved, and recently trial clips of properly classed wool have fetched prices twice that obtained from ordinary unclassed wool (which is what practically all Basutoland wool used to be). Last year the value of the wool exported was about £143,000, and though the price for wool, and consequently the income derived from its sale, varies enormously —the highest figure reached was £715,665 in 1924, and the lowest since 1908, £98,304 in 1937—the BaSotho may reasonably expect a substantial and a greater income than hitherto from this source when the present schemes have had time to take effect.

Stock census returns show that there are about 17,577 taxpayers owning small stock. (The same difficulty in arriving at the proportion of households who own stock obtains as in the case of cattle.) It may therefore be assumed that it is not as well distributed throughout the population as cattle, being concentrated in larger flocks and fewer hands. The average holding, according to the above returns, is 100 per owner, but the size of actual holdings varies from a mere handful to 1000 and more (among the Batlokoa three people owned flocks of this latter size). As regards the effective distribution of small stock the factors which affect the distribution of cattle do not apply to the same extent. *Mafisa* holders are sometimes allowed to keep for themselves the proceeds of the wool produced by the sheep in their care, but on the whole this practice is not followed with small stock to the same extent as with cattle. The concentration of sheep in the Highlands has no great effect, for the owner gets the money for his wool no matter where the sheep are kept. And if he wants an animal for food, it can always be sent down from the posts.

The only other source of wealth exploited within the country itself is

agricultural land. The total area under cultivation is about 749,824 acres, of which 468,640 lie in the Lowlands. This is divided up into fields of various sizes, their average acreage being about 2 acres according to the most recent estimate made by the Agricultural Department. This estimate supersedes that given in official reports (*cf.* p. 20 of the 1937 Annual Report, No. 1854, H.M. Stationery Office, 1938). Each married or widowed woman is entitled to two fields and each married man one field. This division does not always occur in practice. There are numbers of people with more lands than they are theoretically entitled to and/or larger lands than the average: conversely others have fewer and smaller lands than the average, and many have none at all. The soil varies considerably in fertility even within small areas, consequently in the better organised areas people's fields are scattered about so that there should be a fairish distribution of good and bad land. It is not unknown for the politically influential to keep for themselves some of the better land.

Crop production varies considerably according to the type of crop, the type of land, and the season. Taken by and large, the average production is about 2 bags (400 lbs.) per acre. In a good year such as 1936–37, it was 2·6 bags. It is often thought that the country cannot produce its own grain requirements, but such is not the case. For though more grain was imported than exported in four years between 1931 and 1937, this was a period of exceptional drought; between 1919 and 1931 only once was there an import balance.

It must be noted that these figures do not necessarily prove that the country produces all that the people could eat or that everyone did get sufficient food even when there was a surplus grain export. As no political pressure is put upon them to dispose of their grain, and as they enjoy a fair income from their wool and their work under Europeans, which should permit them to meet their extraneous needs without being forced to dip too heavily into their grain supplies, it may be assumed that they do not ordinarily stint themselves to produce this export surplus. But it should be observed that although 1937 was a good year, the average consumption of grain was only 1·86 lbs. per person per day. It should also be observed that over recent years, since 1919, there has been an irregular but progressive drop in the balance of grain exported. There seems to be some suggestion therefore that the country is not finding it as easy as hitherto to support itself. There is, however, no doubt that the country's fertility is such that with the present acreage devoted to agriculture production could be increased with improved cultivation. For the BaSotho are not good agriculturalists and do not make the best of their natural resources, but the Administration is, and for years has been, encouraging them to adopt more productive methods, and though its efforts have not met with

all the success they deserved, it has succeeded in raising the standard of agriculture higher than it was. The present extensive antisoil erosion and reclamation work is also having a notable effect on the productivity of the areas affected. Indeed in the opinion of the Director of Agriculture, the BaSotho to-day are better agriculturalists than any other Bantu group in South Africa, with the possible exception of the BaRolong of Thaba Nchu.

That more progress in this matter has not been made is due to several factors. The BaSotho have not the capital to go in for anything like intensive farming. Land is limited, and few families can afford harrows or other agricultural implements of that sort, and in the two areas where I have worked less than a third of the families even had ploughs. Many, however, could afford to have these implements had they sufficient draught animals and man power to deal with them. The 1937 census showed 123,000 oxen, 29,000 bulls, 186,000 cows. The agricultural ox unit is officially placed at 5 units. Therefore oxen alone could theoretically cope with 615,000 acres of the 750,000 cultivated. Bulls, cows and equines should be sufficient to cope with the rest. It is probable that, even allowing for their lack of condition at the beginning of the ploughing season, there are sufficient draught animals in the country to cultivate all the arable land, but owing to their maldistribution both as regards ownership and geographical location, many have no cattle to use for agriculture and others have scarcely enough. Consequently they have to club together in small groups of three or four or more households or families to collect together a span of oxen as well as necessary equipment such as a plough, chains, yokes and so on. Even so they often cannot get together a satisfactory outfit, and though the desirable span is at least 8 oxen (compare this with the 16 or 18 ox-spans used in the Orange Free State by European farmers, with their double or triple furrow ploughs), many can only collect 6 oxen or beasts, and I have often seen spans of only four. Even then, as figures quoted above indicate, the span has often to be made up of cows, bulls, donkeys, and even horses. Very rarely have the ordinary people animals in reserve for relief purposes. Furthermore, these spans, instead of being able to concentrate on the lands of only one or two households, have to plough the lands of all the members of the co-operative group—to do this they often have to skimp their work or plough until too late in the season, and only in exceptional cases have time enough for other agricultural operations required, such as harrowing and cultivating. So even though it may happen as in 1936 that all the available land actually is ploughed, it cannot be ploughed and cared for as well as it should be.

These considerations apply of course principally to the poorer sections of the people, which actually comprise the major part. The wealthy have

enough cattle to be able to make up their own spans and are able to hire labourers to till their fields: some of them take advantage of this and follow improved modern methods, with considerable profit to themselves; not a few, on the other hand, are not interested, and just carry on in the traditional way (for a brief description, see Pim, p. 161) without making any attempt to improve their production. Their indifference is shared by their poorer neighbours, and this is indeed another factor of some importance contributing to the present position. The MoSotho is not an agriculturalist by tradition, and tends to regard agriculture as women's work (which it used to be), and even if he does not positively despise it, he just is not interested or enthusiastic about it. Working at the mines and in the towns tends to support this attitude, though economic need, education, and the attitude of those who have worked on European farms, who have acquired some sort of regard for it, are slowly changing it. Furthermore, and of even more importance, is the absence of any driving incentive to the BaSotho to develop their lands and improve their agriculture. Naturally, they are gratified when they get a good crop, but they are not unduly perturbed when it fails or falls short of their needs. For they always have the mines and other labour markets to fall back on, where their able-bodied menfolk (even if they are not there already) can earn, without much trouble and without much inconvenience to the rest of the family, the wherewithal to buy food and whatever else they need. They have therefore no real inducement to look on agriculture as their main or only source of food and wealth—as, for instance, have the Chinese peasants, whose only alternatives are often beggary or banditry—and lack the stimulus necessary to make them take the extra care and trouble to turn an indifferent crop into a good one, and generally to make the best of their resources.

Again, as a result of the easy returns of wage-earning in the Union, there is a shortage of male labour at home, and this also has its effect on Sotho agriculture. For, with at least 50 per cent. of the able-bodied adult males out of the country, a great deal of the ploughing has to be left to women and children. However willing they may be, they have not the strength or the skill to control the oxen or to plough properly. Again, for this reason too, it often falls to one man (aided maybe by a couple of small boys) to plough the fields of a single co-operative group, *i.e.* of three or four other families besides his own. It is only to be expected that he will not plough them all with the skill and care that are desirable. For, conscientious though he may be—and many are surprisingly painstaking—he has not the driving incentive which would overcome the inertia and indifference already mentioned, and induce him to cultivate all these lands to the fullest extent.

Prejudice and conservatism also affect the position. This is especially

noticeable as regards the introduction of new crops such as legumes in the Lowlands or the discouragement of crops which are unsuitable for the area concerned, e.g. *mabele*, and to a certain extent maize in the Highlands, where the season is usually too short. Continued propaganda is slowly breaking these obstacles down.

Tyranny of chiefs and fear of dispossession have sometimes been alleged to deter the introduction of new crops or the adoption of better methods. This used to be so in the old days, *e.g.* the instance of Chief Johnathan in the northern part of Basutoland, who for years refused to allow wheat to be grown, saying it interfered with the grazing of the cattle. Nowadays this is not the case, and if the Chief happens to take any notice of agricultural developments, it is to encourage—as, for instance, the Paramount Chief and others—rather than to oppose them. Moreover, dispossession by chiefs, on account of jealousy, though commonly talked about, rarely occurs. I heard of only three vague stories to this effect, but never came across one that could be substantiated or found correct. As regards the opposition of tribal customs, *e.g.* the communal grazing of stalks after the harvest being opposed to winter ploughing, owing to the difficulty of controlling stock, this factor is also apt to be over-estimated. Usually cases of conflict of this sort resolve themselves or are soluble with a little tact, and with the co-operation of the local authorities and people, as indeed has happened in the above example. Several other cases of this sort have recently arisen out of the anti-erosion work at present being undertaken. The putting up of fencing is often regarded as one of the last things the chiefs will tolerate, and yet several areas have, with the willing concurrence of the Paramount Chief, recently been fenced in connection with these same works, as well as with experimental work in pasture management in the Highlands, and in many villages one may see fenced or enclosed gardens, sometimes one or two acres in extent, being used for vegetable growing or as orchards.

Finally, brief reference should be made to that all important phenomenon, labour migration, which has already been touched on. The surplus income derived from agriculture varies from £260,000 to £25,000 (except in the few years when production failed even to satisfy the demand for food). Besides this, there has been an uninterrupted though variable income from wool and mohair. The total income of the country from its products was £760,736 in 1937, and has varied between £1,380,119 in 1918 and £251,427 in 1931. For years this has been insufficient for their payment of tax and purchase of essentials such as grain, clothes, blankets and other such commodities, let alone luxuries. To satisfy these needs the BaSotho have recourse to mine and other forms of labour in the Union. In 1936, 33,450 were recruited for the mines alone, and in 1938 (year ending

30th September), 42,074. They have been accustomed to go to work ever since the opening of the Kimberley mines in the 1870's, but rarely if ever have so many gone out.

Not all these men are away from the country at the same time, but a large proportion are. About 50 to 55 per cent. of the mine recruits are recruited under the A.V.S., and stay, on the whole, a shorter period than those recruited under contract, whose contract usually keeps them away for about ten to twelve months. There are many factors encouraging the men to go to the mines—the spirit of adventure, boredom with village life, lure of wealth, and so on—but of these not the least important is the economic. Some only want a little money with which to buy stock to marry with, or to have as the nucleus of a herd; others need money for food, tax, and clothing. It is difficult to estimate how much money is brought into the country from the mines, for a considerable amount can not be traced. In 1933 when there were labourers recruited for the mines, Sir Alan Pim estimated the income from this source at about £400,000. To-day, with a larger number of recruits, extension of the deferred pay system and the growth of the consular functions of the Basutoland Agency at Johannesburg, this income is undoubtedly greater.

Some of the ways in which this emigration of labour reacts on the nutritional situation have already been considered above, others will be mentioned below.

## Sotho Foods.

We may now turn from this general introduction to a discussion of the foods actually consumed by the BaSotho. The following are the principal ones:—

*Cereals.*—Maize (*poone*) is their principal food and is their most important crop. Various kinds of maize are grown, such as flint (*lehakoana*, including the "ninety day" variety—*teremane*—and Boesman), dent (*lehomo* or *lepolanka*, including yellow dent), and bread maize (*borotho*). The most common are the flint and the bread maize, and they are appreciated both for their taste and for the pleasant appearance of the bread they make. Yellow maize is not popular—they say it "bites their innards"—though it is readily eaten when green. Maize is eaten mainly as meal, cooked in various ways, and is also eaten on the cob and cooked whole. It is also the base for beer and *leting*. A list of Sotho dishes and recipes is given in Appendix IV.

Kaffir corn (*mabele*) is the next most important cereal eaten by the BaSotho. According to tradition it is the oldest grain known to them, and was once the most important. It is widely used in the Lowlands to make bread, porridges of different kinds, beer and other beverages. It

cannot easily be grown in the Highlands, so is there used only by those who can afford to buy it or who have successfully risked growing it.

Wheat (*koro*) is also widely grown. It is a new crop compared to the above. It was introduced to the BaSotho by the first missionaries, who arrived in the country in 1833, and has been extensively cultivated for at least fifty years (128,000 bags were exported in 1893!), except in the northern part of the Territory, where it was for a time objected to by the late Chief Johnathan, as it interfered with the winter grazing. In the Highlands it is grown as much for food as for sale, but in the Lowlands it is regarded mainly as a commercial crop, although its use as a food is slowly becoming more common. Several varieties are grown in the former area, but since is it admirably suited to the production of excellent strong wheat, the people are being encouraged to concentrate on this type (see Reports of the Agricultural Department for these varieties, also for account of experiments for introduction of new varieties). In the Lowlands the people mainly go in for soft varieties. Wheat is mainly used for making bread, and sprouted grain is used in beer brewing.

Oats and barley are grown in the higher levels of the Highlands, and also in the Lowlands near Government camps. These are commercial crops, rarely used for food, except to a limited extent in the Highlands.

*Legumes.*—Peas and beans are widely grown in the Highlands, and only to a limited though increasing extent in the Lowlands. They are mainly grown for food, although a fair surplus is exported. Peas are eaten when green and when dry, and beans mainly in the latter state. Pea pods are sometimes chewed for their juice, and may be cooked as a spinach. Both vegetables are greatly liked by the Highlanders and their immediate Lowland neighbours, who have followed their lead, but they are surprisingly little used elsewhere.

Lentils are also grown for food. They are not common though fairly well liked.

*Succulents.*—Pumpkins and gourds of several kinds are universally grown, and after cerëals form the most common vegetable food. They are used both fresh and sun-dried (in strips), and pumpkin leaves are sometimes used as a spinach either green or sun-dried.

A few small watermelons are grown in the Lowlands.

*Root Crops.*—The only root crops cultivated by the fields are varieties of potato. They are not grown extensively or systematically. Other root crops such as carrots, beetroot, turnips and onion respond readily to a little attention, and are much appreciated as a supplement and relish to the ordinary diet, but they are grown by few. Teaching in the schools, the work of agricultural demonstrators and other influences are now encouraging their production on a wider scale, and in the Lowlands parti-

cularly many little vegetable gardens, complete with stormwater dam and compost pit, may be seen in the enclosures round each household. There tomatoes, cabbages and other vegetables are grown in addition to the root crops mentioned above. In 1937 the number of gardens supervised by the Agricultural Department had grown in a few years to 1700, and there was every likelihood of the increase continuing. In addition to them there are numerous unsupervised gardens, estimated at one or two thousand. This development is of only very recent origin, but if it continues its effects on Sotho diet will be far-reaching.

*Miscellaneous.*—Sweet cane (*ntsoe*) is widely grown in the Lowlands, where it is usually planted with *mabele.* Occasional efforts are made to grow it in the Highlands, but the seasons are often too short. The raw pith of the cane is chewed for its sweet and pleasant juice.

Peaches and other fruit trees are to be found scattered throughout the country, growing in the lands and in the villages. Their fruit is not of good quality, except that grown by some of the more advanced Lowlanders, and is usually eaten before it has had a chance of ripening. Efforts have recently been made through demonstration, and the distribution of thousands of good trees, to produce something better, and in many Lowland villages one may see small, enclosed, and fairly well cared-for orchards.

*Wild Foods.*—Numbers of edible plants are known to the BaSotho, but few are used to any appreciable extent, even by herdboys. A list of some of the commoner ones is given below, but this is by no means exhaustive. Leaves and bulbs (*khukhu*) of the *bolila* (*Oxalis convexula, O. semiloba,* and *O. Smithii*), and *bolila ba lipoli* (*Plantago major*), *seoeliloetla* (*Rhynchosia Totta*), *mantsokoane* (*Asclepias gibba*), berries of *monnamotsu* (*Myrica conifera*), and wild raspberry and blackberry. The herdboys and women and children also eat the bulb of the *monakalali* (*Cyperus usitatus*) and leaves of wild sorrel, raw and cooked. Some of the commoner spinaches are *sebista* (*Lepidium capense* and *L. Schinzii*), *leshokhoa* (*Xysmalobium lapathifolium*), *lerotho* (*Lepidium myriocarpum*), *montsoko* (see above), *moetse oa pere* (?), *serue* (*Chenopodium album*), *papasane* (*Nasturtium fluviatile*), *mololo* (*Cynanchum virens*), *lefokotsane* (*Thalictrum minus*), *thepe* (*Amaranthus paniculatus*), *seshoabohloko* (*Solanum nigrum*), *tlhako ea khomo* (*Sisymbrium capense*), and *monyaku* (a term which covers seven different plants). These are taken from Mabille's and Dieterlen's Dictionary, 1937. I did not have the plants shown to me identified by a competent botanist, but as they are commonly known to practically every Mosotho where I was, I should think that this classification is fairly accurate. But whether all the varieties of plants by the term *monyaku* are all used as spinach I do not know. For a brief description of some of these, as well as of others not

included in this list, see L. F. Levy (3). An outstanding exception to this is the category of plants commonly known as spinach (*moroho*), which consists of a dozen or more varieties. They are widely used throughout the country. They are eaten fresh, and are cooked either separately as a relish to the usual maize pap (*paté*), or together with the mealie meal to flavour the pap. So far as I know it these spinaches are never dried and stored for future use. They are regarded chiefly as a food for women and children, and are not often eaten by men.

## Animal Foods.

*Milk.*—Cow's milk is always used when obtainable. It is almost invariably taken with some other food, not by itself. If used fresh it is usually boiled—it is rarely taken raw except by herdboys sucking direct from the cow; otherwise it is allowed to curdle (see Appendix IV). Goat's and sheep's milk is also used, but neither is liked as much as cow's milk, and some people who have no milch cows (or an insufficient number) prefer to go without milk at all rather than use the milk of their sheep or goats. Their herdboys do not, however, share their fastidiousness.

It is worth noting that only those cows are milked which have recently calved and are suckling their offspring. As soon as the calf is weaned, the cow ceases to be milked. The BaSotho say that unless the calf is there, the cow hides its milk—hence when a young calf dies they try to keep its mother as a milch cow by presenting it with a dummy made out of the calf's skin or by bringing its predecessor back to suck. This practice of allowing calves to suck so long is doubtless to their advantage, as they would otherwise have to struggle along on the very poor grazing immediately round the village, but it certainly diminishes the quantity of milk immediately available for the family. It might be mentioned that this practice is widespread in South Africa among Europeans as well as Bantu.

*Meat.*—Meat, next to beer, is one of the most prized foods commonly used by the BaSotho. It used to be one of their principal foods, but is now comparatively scarcé. Lack of it gives rise to a real craving, which, some say, beer drinkers experience worse than others. People try to relieve it by means of tinned fish—or meat—or a mess of beans.

Formerly the people had beef, mutton, and the meat from the game with which the country used to be stocked. This game has now been all but exterminated.

Cattle are killed mainly on ceremonial occasions, such as weddings, funerals, initiation and baptism of adults, and are rarely butchered solely and expressly for meat, except by the very rich and a very few of the chiefs who follow the traditional custom of killing for their court. It was surmised by the Agricultural Department that 76,000 cattle were consumed in

Basutoland in 1937. No data are available as to what proportion of this was eaten only by BaSotho. A large portion of the meat is cooked for the benefit of the guests and eaten then and there; the rest is retained by the host for the private use of his family and is used slowly over a week or so. On many occasions he is enjoined by custom to share part of the animal with certain of his relatives, and to give them certain specific parts. Sheep and goats are also widely killed on ceremonial occasions—occasions such as the above, where poor people are involved who cannot afford a beast, as well as various small magico-religious and ordinary social occasions. Here most of the meat is shared with the guests and very little given to relations to be taken away, though of course the host keeps some back for himself. Those who can afford to—those of the "wealthy" and "less wealthy" classes (see below)—also kill small stock purely for food. Most killing, especially butchering, takes place in winter when the meat can be kept longer without going bad.

People say they like beef better than mutton because the meat is stronger. Social associations of beef with ritual and wealth probably also have something to do with determining this preference. They also prefer persian or "bastard" sheep to merino, as they are fatter and their meat more flavoured. Incidentally, much of the fat of these sheep is not eaten, but is used to make soap (by boiling with caustic soda) and ointment.

Horse flesh is only eaten by a few BaSotho, for the majority share our prejudices in the matter. Pork is considered a great delicacy (though I am told that some do not eat pigs, merely using their lard for ointment). Pigs are mainly kept in the Lowlands, but no particular attention or care is paid to them. They are scavengers, and are said to be the effective carriers of tapeworm. Chickens are kept for the sake of their meat and eggs. They are not well looked after, though they may occasionally be fed with grain and an attempt may be made to protect them from hawks, and as a result their production and increase is poor.

Birds, with the exception of carrion birds, such as vultures, crows, and certain kinds of hawk, and all of the few varieties of small animals that still remain, such as hares, dassies, and mice, are considered edible. Snakes are also considered edible, but I never came across anyone who would admit to having eaten one.

*Fish.*—Basutoland rivers are poorly stocked with fish, and such as they have, barbel and yellowfish, make uninteresting eating. Few people take the trouble to catch them, except herdboys, who occasionally fish for sport, and no one regards them as a significant article of diet.

*Salt.*—At present the trading stores are the only suppliers of salt, and what other sources of supply the BaSotho had I do not know. It is a valued commodity and is widely used, though in very small quantities, both for

cooking with food and as a condiment to flavour cooked food. (In the three and a half months I was with Family 3, see Appendices I–III, I do not think we had salt more than half a dozen times.)

*Water.*—The people pay little attention to the purity of their water supply, though they naturally prefer clear spring water when they get it. It is always drunk fresh and is not boiled except for cooking and for making tea or coffee. I have no data regarding its mineral content.

*General.*—In addition to the foods, described above, the BaSotho have become accustomed to the use of imported foodstuffs, the extent to which they actually use them varying in the different parts of the country. Of these foodstuffs the more important are salt, sugar, tea, mealie meal, cheap sweets, flour, and tinned meat, fish, milk, and fruit. In the Highlands they are still regarded mainly as luxuries, to be used chiefly on festive occasions, though the wealthier people buy a little tea and sugar for ordinary use, especially in winter, to counteract the cold. In the Lowlands they are almost regarded as necessities; certain sections of the people, such as teachers and other regular wage-earners, and well-to-do people such as chiefs and other authorities, use them regularly, and in some households the old type dietary has largely been displaced by a pseudo-European diet of tea, sugar and finemeal bread. Moreover, the use of refined mealie meal and flour is growing. Ostentation and taste both prompt their use, and the fact that they are ready to cook encourage many people to buy them during the weeding and harvesting season to save their womenfolk the time and labour of having to grind grain in addition to their ordinary agricultural tasks. Many BaSotho nevertheless dislike these refined meals, and say that they have less body and substance than the wholemeal ground by themselves. Medically, it appears, there may be something to be said for this view, and it is interesting to note that the incidence of pellagra in the Territory has been tentatively ascribed to the use of milled maize (Annual Medical Report, 1935). The alternative cause suggested, namely, the use of kiln-dried maize, which was imported in large quantities the previous years owing to an acute shortage of grain produced locally, does not seem to have been supported by recent facts, for though the importation of this grain has decreased if not been entirely suspended, the incidence of the disease has steadily increased. The whole question, however, requires closer examination than has yet been made before any definite correlations or deductions can be made.

## Consumption of Food.

After this brief description of the foods known to and used by the BaSotho, the extent to which they are actually used should now be considered. Here there are three principal lines of variation—differences

between Highlands and Lowlands; differences between different sections of the community; and seasonal differences.

In Appendices I–III extracts from the diet records of six Highland families are given in progressively greater detail. Appendix I gives the foodstuffs eaten by these families, Appendix II gives the different dishes eaten, and Appendix III gives the actual meals consumed, and in some cases the actual quantities of food. The records cover from three to ten months, and the extracts relate to the last week in each month, except in the few cases where gaps occurred when the last seven recorded days of the months are taken. I kept other records besides these shown, but as they were in no way peculiar or showed nothing new, they have been omitted.

The following are the main points to which attention might be drawn:—

1. Each of these families had food every day at least twice a day, and very often more frequently. In other words, there was no actual shortage of food, although the supplies of Family 6 were very nearly exhausted. The BaSotho, unlike many other tribes, do not have any definite "hunger months," though some families may have to tighten their belts in the late summer before the new crops ripen, and even if their grain supplies do run short the trading stores are there from which they may buy grain. The BaSotho, in common with other South African tribes, sometimes tend to sell part of their grain to traders in winter in order to buy goods such as blankets and clothes, and then have to buy it back again in summer when their supplies run out. Many of them, as mentioned above, are ablė to produce enough to see them through till next harvest, but in their improvidence they do not make an estimate of what they will need, keeping what they will want, selling only the surplus and paying the balance of their purchases with cash. As it is, therefore, they sell when prices are low, and buy when prices have risen, and thus unnecessarily tend to deplete their already slender resources. It is interesting to note that some BaSotho are shrewd enough to profit by this themselves and speculate in grain, buying in the winter and selling in the summer. But practice varies considerably, and it was observed that in 1937 practically the whole of the large grain surplus of that year was hoarded.

2. Maize is eaten in greater quantities than any other food. Practically all of the six families ate maize in some form or other on at least six days in the week, and very often on all seven. Wheat was the only other food eaten in any great quantity, but it was never used to the same extent as maize, and was often used but sparingly—often it was used only once or twice in the week, and several families did not use it for months on end. The reason for this is partly its greater cash value (though Staples, contrary to my own earlier experience in the same area, found that maize fetched higher prices), and partly the fact that maize is a traditional food-

stuff, whereas wheat is comparatively new, and also that maize lends itself to a greater variety of recipes and can be more easily cooked. Thus it is noticeable that the wealthier families such as Nos. 1 and 2 used a lot of wheat, though never to the exclusion of maize, whereas the poorer families used it comparatively seldom, and sometimes went without it for days on end, and also that at harvest time wheat consumption increases only in the case of the poorer families, completely to die away during the late summer. (The apparent exception of Family No. 2 is due to the fact that its wheat crop was damaged by stray stock.) Bread made from wheat is tastier than maize bread (and is invariably provided at feasts and sometimes entirely replaces it), and so for this very reason is eschewed by poorer families as a part of their regular diet—for, as one woman put it, "because we like it, it does not last."

3. Absence of *mabele*. This is typical of the Highlands. The only time when *mabele* is used there is when the sprouted grain, bought from the stores, is used to make beer. Very occasionally a wealthy man may import a couple of bags, but as the transport makes it so expensive it is sparingly used for anything other than beer brewing. A very few people successfully grow it in some of the warmest valleys. In the Lowlands, on the other hand, *mabele* is extensively used, the people eating practically all they grow.

4. The consumption of vegetables is fair, but not as uniform as might have been expected, and though vegetables of one sort or another are available throughout the year no family made as full use of them as it might have done. Spinach, for instance, was plentiful, though a mile or so away from the village, and at least three of the six families were too lazy or indifferent to take the trouble to collect it except very occasionally. (During the time I was there Family 3 did not collect it more than three times.) The availability of fresh vegetables depends on the season, but dry peas and beans may be had all the year round, and it is noteworthy that Family 1 had peas regularly for eight out of the ten months recorded. It is also interesting to note that two families grew vegetables in addition to using wild ones, such as spinach and legumes grown in the lands. The head of Family 2 had learnt gardening when working for a Free State farmer, and the head of Family 5 had been taught at school—he was the local teacher. Both had small but well-cared for gardens. A son of Family 3 also tried to start a garden, and begged a few plants from the two mentioned above, but he gave up when the fowls rooted up these plants. It has often been said that the chiefs are opposed to vegetable gardening, as it involves the enclosure of land, small in extent though it be. But this, I think, is more of an excuse to conceal the laziness of the informant rather than a real reason, for, as has already been mentioned, one may see small enclosures in many villages, and as in the above cases, if people wish to

establish a small plot no objection is made. Moreover, for generations the BaSotho have been used to growing tobacco, and as often as not they grow it in a small protected garden in the village rather than in the fields or elsewhere in the open.

5. As regards milk, the position is that only four of the six families had any milk at all; of these only two had it in any great quantity, and even they went short in the late winter and early spring. Moreover, even in the summer months when grazing is good, Family 3, which had two cows, had occasionally to go without milk once or twice in the week, and sometimes on those days when milk was available there was enough only for the children. Family 4 was entirely dependent on a surplus from the Chief's household (and was probably cut off altogether when the Chief moved most of his cattle to a new village later in the year). This scarcity came as a surprise to me, as this was in the very heart of the Highlands, and there was plenty of grazing round the villages. It is, however, due solely to the fact that these families, representing, as will be shown, a quite large proportion of the population, simply did not have any cattle. Family 6 had about a dozen sheep, but preferred not to keep them at the village, and Family 3 had a few more cows which were held by relatives elsewhere as *mafisa*. They also had about twenty sheep, which were kept by a friend in the village, but they were not used for milking.

6. Not all the milk was consumed as whole milk, but very nearly half was eaten as *mofehlo*—curdled milk with the butterfat removed. *Mofehlo* is valuable both as an ointment, as an exchangeable commodity. I was told that the Highlanders sometimes export to the Lowlanders. I was also told that the BaTlokoa extract this butterfat to a greater extent than other BaSotho, so it may be that in this particular these records cannot be taken as representative of the Highlands generally.

7. As regards meat, the position is somewhat similar to that in connection with milk. Four families are recorded as having meat, and of these two had it with some regularity. Two families are recorded as having no meat; one of these also went without milk. (Note.—Owing to irregularity with which meat is eaten, these extracts, which presuppose a certain regularity—which *does* obtain so far as other foods recorded are concerned—do not reflect the position quite accurately. On the one hand it was actually a matter of chance that Family 6 is shown as not having had meat—it did have some meat, as an occasional gift from the Chief, though so far as I know this only occurred four times in five months, and constituted its only source of meat. Similarly Family 3 also had more meat than is suggested, through occasional gifts of meat—three sheep from the Chief to feed half a dozen tax-collectors, who were billeted there, and two sheep from me when my own meat craving grew unpleasant. On the other hand, those families

shown as having meat during each of the weeks referred to actually did not have meat at the same rate during the rest of the month, and more often than not these were the only times they had meat during the month.) The second milkless family (No. 5) had a cash income which enabled an occasional sheep or chicken to be purchased for food. But whereas those who have milk have it for the most part fairly regularly, they have meat only at irregular intervals, and may go for weeks without it. Then when it comes, it comes in large quantities, and rather tends to encourage people to overeat themselves for the few days for which it lasts.

Another point of difference is that in times of shortage, such milk as is available is usually given to the children first, infants getting it before older children, whereas in regard to meat the adults tend to have more than their children. This is due to the fact that for many meat is to be had only at feasts and celebrations and at court on the rare occasions when the Chief kills for his people or carcases are brought in in connection with cases of stock theft. Children, except those living in the village, are not allowed to attend the court or these festivities, and so will only have such meat as their parents have managed to bring away with them. Usually this will amount to very little, as such meat is supposed to be eaten there, and in any case is not very much to begin with.

8. With regard to quantities consumed, the figures obtained are not sufficiently detailed to allow a satisfactory estimate to be made of the actual intake of food. Nevertheless they do show that there are considerable variations in the amounts of grain and other foodstuffs as between different families. Thus, for instance, the details given for richer families, such as Nos. 1 and 2, show that the average grain consumption for some months was about 3 lbs. per head per day, whereas those for Families 4, 5, and 6 show a consumption of 1 lb. to a little over 1½ lbs. (As the figures for these latter families relate to the late summer and early autumn months before the new harvest was in, when supplies were not as plentiful as in winter and early summer, to which the figures for Families 1 and 2 refer, the comparison between the two sets is not perfectly fair. But as it is highly improbable that Families 1 and 2 reached the same low level in February and March, for general purposes the comparison may be allowed. Note in this connection that when the grain consumption of Family 2 dropped to the not inconsiderable figure of about 2 lbs. per person per day, it was low enough to provoke comment and self-pity from the head—a fact which suggests that this family was used to a higher standard of living than, say, Families 4 and 6.) As regards the total average consumption of food per head, taking into account meat, milk and vegetables, the gap between the wealthier families and the other is further increased.

9. Finally, it should be noted that some families enjoy a greater variety

of food and of dishes than others. Thus, for instance, Family No. 1 sometimes had as many as eight different maize dishes besides having wheat, milk, meat, and vegetables as well, whereas Family No. 3 seldom had more than three different sorts of maize dishes, and had less wheat, meat, milk or vegetables. Families No. 4 and 5 occupy an intermediate position. These variations can be closely correlated to different degrees of wealth, and it is only the richer people who normally can afford to have a wider and more varied diet than others. Some of the foods they have such as *Motoho* and "Bread B" are more appetising than other dishes, and so are consumed more quickly; they also sometimes involve the throwing away of some of the grain in the form of chaff (though this on the whole is so little as scarcely to warrant comment). The same considerations apply to the use of wheat as compared with maize. Moreover, the preparation of many dishes entails greater work than the preparation of one or two, and so is undertaken only by the wealthier households which are usually larger.

## Discussion.

In view of the considerable variations in the dietaries of these families, their representativeness must be assessed, first as regards the Highlands and then as regards the Lowlands. As these differences in diet are largely related to differences of wealth, the economic status as measured by stock ownership may be taken as our criterion.

On this basis an analysis of the sixty-six households living in or near the Chief's village gives the following distribution:—

| Type of Household. | Number. | Percentage. |
|---|---|---|
| *Wealthy.*—Sufficient stock for regular meat and milk (about 20 cattle and 50 sheep). Representative: Family No. 1 . . . . . | 6 | 9 |
| *Less Wealthy.*—Sufficient stock for regular milk and occasional meat (less than 20 cattle, etc.). Representative: Family No. 2 . . . . | 19 | 29 |
| *Middling.*—Sufficient stock for occasional milk and rare meat (less than 10 cattle, etc.). Representative: Family No. 3 . . . . | 19 | 29 |
| *Poor.*—Little or no stock, but helped by wealthy friends and relations. Representative: Family No. 4 . . . . . . . . . | 9 | 13 |
| *Very Poor.*—Little or no stock and no wealthy friends, etc. Representative: Family No. 6 . | 13 | 20 |

(Professional families such as No. 5 are rare in the Highlands. This family actually had no stock at all.)

This group is sufficiently typical of the Highlands for our immediate purpose, although so far as I could judge it appears to be somewhat wealthier than the average. The 1938 stock census gives a proportion of not more than 55 per cent. owning cattle, and 57 per cent. owning small stock in the Mokhotlong District, after due and generous allowance has been made for vague connotation of the term "owner," which is somewhat lower than the average shown by the above group. This group also appears wealthier than the group from another Highland District, Quachas Nek, regarding whom figures were supplied to the Pim Commission (see Appendix VII).

According to this assessment, then, the position in the Highlands may briefly be summarised thus: the diet of about two-thirds of the people, as represented by Families 1, 2 and 3, is fairly good both as regards quantity and variety, and that of about a third is deficient in either or both of these respects. As regards particular foodstuffs, only about a third get meat in anything like regular quantities, the rest have no meat except at irregular intervals of weeks. Again, as regards milk, about half of the people have milk regularly for the greater part of the year, if not the whole year, about a quarter have it occasionally, and about a quarter rarely if ever have it. In 1938 there were 14,444 cows in the Mokhotlong District (excluding a small area in the north-west corner). This gives an average of a little under three cows per household owning cattle, or 1·6 cows per household. Included in this number are sterile cows, cows without calves, many of which are not milked (there were 3606 calves) and cows due to calve, also not milked, so that the number or average of cows actually giving milk is somewhat lower than bald statistical statement would seem to indicate. On the other hand, some milk is obtained from sheep and goats. Among the BaTlokoa this was insignificant so far as the people generally was concerned (though herdboys made some use of it), but according to Mr. Thornton this is not representative of the BaSotho as a whole.

It might also be mentioned that the actual production of milk varies greatly—a good milker may give as much as two gallons of milk a day, excluding that consumed by the calf and herdboy suckling *moso kotso,* during the height of the season, while a poor milker may not give more than a couple of quarts. In winter this supply dwindles away to practically nothing. As regards grain, most people get enough to satisfy their ordinary appetite, though in the autumn a small proportion may have to go on fairly short rations.

There is one final point which calls for comment, and that is that the position is not as good as it was, so that the children of to-day are not as favourably placed as were their fathers. Eighty years ago when the

Highlands were first populated, the people had more meat and milk than they have now, and except during the early years of their settlement when their crops failed regularly, they even had more grain. Hunting used to be excellent, but to-day practically every sort of game has been exterminated. Almost everyone had cattle and small stock, but to-day many have none. Moreover, previously most of the cattle used to be kept at the village where the fullest use could be made of them, whereas, even though they are in the heart of the pasture land of Basutoland, many have to keep a proportion of their cattle at the remote posts for several months of the year, and sometimes, if the posts are sheltered from winter cold, for the whole year. Finally, each household used to have as much ground as it wanted to till, whereas they are now being restricted. Some families are even entirely landless, *cf.* the figures quoted from Quachas Nek, and my own experience in the Mohales Hoek area, where I worked for a time. I never heard of landless households among the Tlokoa, but it is not impossible that there were a few. For this reason, as also for the various reasons given above, which handicap and preclude intensive cultivation, family production has not been able to expand very much, and in many cases it has been reduced, and, as shown in Appendix II, may in some cases be inadequate even in a normal year.

So much for the Highlands. In the Lowlands the position in some ways is a little different. Wealth is somewhat differently distributed, leading to more or less corresponding differences in diet. The gaps between the "Wealthy" and the "Very Poor" is greater, for on the one hand there are Chiefs who have an income of several hundreds of pounds a year (there are only two such Chiefs in the Highlands), coupled with a substantial revenue from their flocks, lands, and courts (a total revenue which is greater than anything obtaining in the Highlands), while on the other hand there are peasants who have neither stock nor land. The Chiefs of course have considerably heavier obligations than ordinary commoners, but in spite of these they manage to live very comfortably, and can also afford racehorses and motor-cars. There is unfortunately no data available regarding the actual distribution of wealth as between the classes described above, so it is impossible to make specific comparison with the Highlands; hearsay, however, would make the percentage of "Wealthy" and "Less Wealthy" smaller than in the Highlands, and the proportion of the "Poor" greater. This estimate the greater exodus of labour from the Lowlands, which is about twice that proportionally from the Highlands, would seem to support.

There is no reason to suppose that the diet of these different economic sections differs in type from the representative diets already given, except for the general differences detailed below. Several of these differences

have already been noted, such, for instance, as that less wheat and very much more *mabele* is eaten in the Lowlands. Other differences are:

1. Peas and beans are eaten and grown less.
2. European foodstuffs are more widely used.
3. Less milk is available. The actual ownership of cows may be similar to that obtaining in the Highlands, but their availability is not as good, for only a small percentage (about 25 per cent.) can be kept near the villages. Consequently many people who have cows are unable to make use of their milk and are obliged to let it be consumed at the cattle posts by calves, herdboys, and their dogs. A few people may have a little milk when they bring their cows down to graze the stalks in the winter, but they get little milk at the end of the winter, when grazing is poor, and in any case usually have to send them back to the posts during the summer. (It may be noted that a few people occasionally have curdled milk brought down from the posts in leathern bags. But it is a laborious business and is not often practised. It is noteworthy that though they are a pastoral people the BaSotho have not evolved their own method of conserving their milk in a durable and handy form, and have not yet adopted the European methods of cheese-making.)
4. As regards meat, the position is more complicated. It is probable that fewer people, in proportion to the Highlanders, kill specifically for meat either regularly or occasionally, owing to the custom whereby friends kill in irregular rotation and share out the meat, but such meat as is available is better distributed than among the Highlanders. It is probable too that such meat is more evenly consumed, as the intervals between each supply are more regular. Moreover, butcheries have been established in and near the camps and large villages and along the principal highways, where they enable people in the neighbourhood to buy meat in small quantities with fair regularity. (There were at least two butcheries among the BaTlokoa, but they were patronised principally by travellers and had not yet become established in the ordinary domestic life of the people.)
5. Regarding the actual amounts of food consumed by the Lowlanders, there are no detailed data available. Recently, however, an official estimate of the total consumption throughout the Territory is about 5 per cent. more than the amount of maize produced, 4 per cent. more than the *mabele* produced, 55 per cent. of the wheat produced, and 98 per cent. of the peas and beans produced. This gives an approximate figure of 1·86 lbs. of assorted cereals and legumes, per person per day, for the crops returns for 1937, which was an exceptionally good maize season, and very good for other crops except the Lowland wheat crop. The estimate and calculations are admittedly approximations, so that this figure cannot be taken as

absolutely accurate, though it probably gives a very fair representation of the position.

As regards the details of cooking, recipes, times and frequencies of meals, the Lowlanders, according to all accounts, follow the same ways and habits as the Highlanders, in so far of course as is compatible with the differences mentioned above. Minor differences are, however, mentioned in Appendix IV.

Finally, as regards the diet of (recent) past years, the present diet of the Lowlanders also represents a change and deterioration, for though the BaSotho suffered terribly during and after the Zulu Wars (they were reduced in their desperation to cannibalism for a short time), and again during the various European wars, they prospered greatly during the last century, and seem to have been in much the same position as the BaTlokoa of sixty years ago, with plenty of grain and game, and with their cattle near the villages. The turning-point came earlier than among the BaTlokoa and other Highlanders, and may be said to have occurred towards the end of the century when the people began to penetrate into the lower and hitherto untouched valleys reaching up into the mountains.

*Diet and Health.*—The proper evaluation of dietaries described above, as well as of the general type of diet of the BaSotho, is essentially a technical task, and will not be attempted here. It is, however, a commonplace that diet and health are different aspects of the same thing, and so perhaps a few general correlations between the two may be permitted.

The health of the Highlanders was described in 1936 by the late Dr. Motebang, the local Medical Officer, as good. No diseases directly attributable to malnutrition were to be found to any extent, although to the presence of some malnutrition the incidence of some illnesses, such as pneumonia and even tuberculosis, may be attributed. So far as mine recruiting was concerned, very few applicants had to be rejected on medical grounds. In the year ending 30th September 1936, it was a little over 9 per cent. (58 rejects to 620 recruits); for the same period ending 30th September 1938, it was a little over 6 per cent. (48 rejects to 775 recruits). The decrease is mainly attributable to the two factors mentioned below.

As regards Basutoland as a whole, the people's health excites no comment one way or another. There is no great incidence of specific deficient diseases, such as scurvy, rickets and the like, although, as will be seen from the table given in Appendix VIII, scurvy occurs regularly, though to a limited degree. (A subscorbutic condition is said to be prevalent during the winter months.) Pellagra, on the other hand, which was not recognised in the Territory before, has been widely observed since 1932, when it was first brought to the attention of medical authorities. It has been ascribed tentatively to the use of kiln-dried maize or to the use of refined meal or

flower, but no definite correlation with either of these factors has either been established or disproved. It may be noted that its incidence varies seasonally as is shown by the following table:—

| | Mafeteng. | Leribe. | |
|---|---|---|---|
| | 1935. | 1934. | 1935. |
| January | 15 | .. | 19 |
| February | 9 | .. | 5 |
| March | 4 | .. | .. |
| April | .. | .. | 4 |
| May | .. | .. | .. |
| June | .. | .. | .. |
| July | .. | 1 | .. |
| August | .. | .. | .. |
| September | 1 | 1 | .. |
| October | 4 | 16 | 6 |
| November | 4 | 9 | 2 |
| December | 8 | 10 | 16 |

(These figures are not entirely satisfactory for comparative purposes owing to the difficulty due to various causes in detecting the disease in its early stage.)

Dyspepsia and constipation, for which figures have been given in Appendix VIII, are attributed to Sotho diet being "unbalanced, badly cooked and monotonous" (Medical Report, 1935). In earlier reports (Medical Report for 1928) it is also suggested that the incidence of acute appendicitis, principally among BaSotho living in the Camps, may be due to a change in their diet (in favour of a pseudo-European diet of white bread and tea) and richer European foods than they are accustomed to.

Regarding the general health of the people, it might be mentioned for what it is worth that in the opinion of residents of long standing and of the older BaSotho themselves, that the physique and health of the people is not what it used to be, and that the younger BaSotho are less energetic and active than their fathers were. One MoSotho said that when he was young men thought nothing of doing such things as running from Peka to Leribe or Maseru (12 or 35 miles), but that such feats were unknown to-day. Miners on the Rand say that the BaSotho have not much physical power but that they are tough and have greater endurance than other peoples. Statements such as these are, however, unsatisfactory evidence, and though the opinions cited are widely held, I have not been able to get data of a less

subjective nature. Figures for rejects among applicants for minework are not of much help here. In 1935 Sir Alan Pim mentioned that the percentage of rejects was 25 per cent. This figure has now changed to a little under 10 per cent. in 1936 and in 1938 to a little over 6 per cent. (5945 and 2734 rejects to 33,450 and 42·074 recruits respectively), but whether this is partly due to an improvement in the health of the people it is impossible to say. The principal factors which have caused this drop are on the one hand the increased skill of the permanent recruiting agents in weeding out the outfit before sending the rest for medical examination, and, on the other, a lowering of the standard of health and development required to include what is commonly known as the "C" group, people who previous to the present expansion of the industry would not have been recruited. These low-grade recruits are detailed for surface rather than underground work.

In the old days the principal activities of the men were fighting, hunting, and sitting in the *khotla*. The former were, however, only occasional pursuits, and fighting seldom went beyond cattle raiding to the extent of becoming rigorous campaigning. To-day these two have entirely fallen out of the men's life, and the only things that can be said to have taken their place are periodic spells of European employment, either on the mines or on farms, which begin at the pubative age of eighteen years, and may continue in the case of mine labour until he is about thirty-five or forty, and in the case of farm labour until a later age. With few exceptions do they take part in agriculture except for ploughing and assisting occasionally at work parties, where beer is available, and at home for the most part they sit about in indolent inactivity, do odd jobs round the house or visit their friends. Nevertheless, when they are interested in some physical activity or are obliged to work hard, they show great energy. They can, for instance, dance the tiring *mohobelo* dance for half a day and more with scarcely a pause, and when put to it can plough their fields for several days for nine hours and more on end (though usually out of deference to themselves and their overworked cattle they usually only work for five or six hours). At the more exhausting tasks of weeding or of threshing grain they do not work for more than about five hours, including frequent rests, and working under the stimulating influence of company, food, and song. What causes this lack of energy and stamina is, as indicated above, impossible to say, but short nights (as children their rest is repeatedly broken and disturbed by their elders), and as adults they do not sleep more than seven hours, if as much, in summer, though in winter they sleep longer—considerable sexual activity may have as much to do with it as their diet and the lack of social inducement to work hard.

Women, on the other hand, are capable of greater and more prolonged physical efforts than men, and though they have not the sheer physical power of men, they sometimes show astonishing feats of strength and endurance. The bulk of the agricultural work falls on them, and for weeks on end (with, however, Sunday being observed as a day of rest) they daily spend as much as nine hours in their lands weeding, harvesting, or threshing, and sometimes in the height of the season they may work in the fields as much as twelve or fourteen hours a day. In addition to this they often have to walk a mile or two to and from their lands, grind grain for their family, and attend to their ordinary household tasks, thus adding an hour or two to the day's work. (It takes from seven to fifteen minutes to grind, without interruption, a pound of grain, the variation in time being dependent on the hardness of the grain, *i.e.* the variety, the amount (after half an hour the worker begins visibly to tire and to slow down), the efficiency of the grindstone, and the skill of the worker.) At the height of the agricultural season women really work themselves to a standstill, and I have seen them so exhausted at night that they fall asleep over their food. In the slack seasons they are still kept fairly active, as besides the ordinary household routine they have to smear and plaster the huts and courtyard, wash the family's clothes, fetch firewood, and look after the children. It would be interesting to know whether their greater endurance and capacity for work as compared with the men is due to their being used and trained to it, or to biological differences. The only differences in their diet is that they sometimes have more food than the men, make more use of spinach and other green foods, and of "soft" foods such as *motoho*, and they sometimes have more milk.

Before leaving the subject of diet and health, the relation of diet and physical development may briefly be described. No figures are available regarding weights and other physical measurements, so that no significant deductions and no comparison with the development of Europeans or of other native tribes (such, for instance, as the allied BeTswana at present being examined by Dr. B. Squires of the Bechuanaland Protectorate Service) are possible. This description may nevertheless be of some general interest.

Sotho babies at birth look much the same in point of physique as European babies, although, according to Dr. Vollet, they are usually somewhat lighter and smaller, particularly with regard to the head. (Weights are now being kept by the newly established maternity section of the Maseru Hospital, but they are not yet sufficiently numerous to be of value.)

During their first two years they grow rapidly and strongly. They are tenderly if somewhat crudely nursed throughout this period, and are rarely left unattended either by their mother or by a nurse. At first they

live entirely on their mother's milk. If the mother dies or is too weak to suckle them, they are either suckled by their father's mother if she has milk or else reared on cow's or condensed milk. They are never given a wet nurse other than the grandmother. After a few months (2 or 3) they are gradually introduced to other foods such as boiled milk, or unfermented *motoho* (sensible mothers are said to avoid giving them fermented foods such as certain types of *motoho*, on the grounds that they "make their blood bad" and provoke stomach and skin troubles), and within a year to solid foods as pap and bread. The young nurses, however, are sometimes a little irresponsible, and give the infants consigned to their care boiled and roasted maize and other hard foodstuffs, albeit sometimes previously chewed and softened. As time goes on these infants are introduced to other foodstuffs until by the age of 1½ or 2 they are eating practically all adult foods, with the main exception of beer and *leting*. They are, however, still allowed to suckle, and this they do frequently, though at this stage more for the sensual and psychological satisfaction they derive from it than as a simple source of food. They are usually weaned when about two years old, though this may be done sooner if the mother has inadvertently conceived again (for until the child is weaned she is supposed to abstain from sexual intercourse, or else indulge only in *coitus interruptus*), or later if the father is away and hopes to keep her faithful by denying her her full sexual freedom. I am told too that some of the more sophisticated natives have taken to weaning their children earlier, after the European custom.

Weaning marks a great change in the child's life, and instead of being sheltered and pampered by their mother and nurses, they are now left to fend for themselves. They are now fed with the other members of the household instead of being given preferential treatment, and where there is a shortage or limitation of food they may definitely have to compete with their elder brothers and sisters. Moreover, where there is a shortage of milk they may have to do without it in favour of a *nouveau-né*. This change is noticeably reflected in their appearance. Until they are weaned they are plump and in good condition, but thereafter they rapidly become thinner, and soon develop the characteristic bulging abdomen. This loss of condition is, however, noticeably less among children coming from the wealthier homes where there is an abundance of food and where there are servants who continue to feed and attend to them.

Children usually remain somewhat thin and boney until they reach puberty. Soon after this, at about the age of fifteen, they begin to fill out and put on flesh. Girls, however, seem to develop more quickly than boys, and throughout their life they seem to be somewhat heavier and better conditioned than boys of the same age.

On the whole the physique of the BaSotho is good and compares favourably, so far as general appearances go, with that of other natives, particularly the Betswana. Outstanding specimens are rare. The average height of the men is between about 5 feet 6 inches and 5 feet 8 inches, and their build is usually lean and wiry. The women are some three inches shorter and on the whole are plumper. It is noteworthy that both respond to the diets such as they get, in the case of the men on the mines, and in the case of women in domestic employ. On the mines the weight of the men almost invariably increases by a few pounds.

The correlation between economic status and physical development and appearance is close. It is usually easy to pick out by their appearance the well-to-do men in a tribe, for apart from their clothes, which are often better, they are usually well built, strong-looking, and sleek with smooth, glossy skins. As they get old they usually get fat and pot-bellied—even gross—and their womenfolk often attain to huge proportions.

## APPENDIX I.

### Short Summary of Foods Eaten during Last Week of Each Month (December 1935–November 1936).

*Family No.* 1.

| Month. | Wheat. | Green mealies. | "Mela." | Ordinary mealies. | Vegetables. | Milk. | Meat. | Eggs. |
|---|---|---|---|---|---|---|---|---|
| Dec. . | .. | .. | .. | .. | .. | .. | .. | .. |
| Jan. . | ? | .. | 6 | 7 | .. | 7 | .. | .. |
| Feb. . | 1 | 1 | 3–7 | 7 | 1 | 7 | 1 | .. |
| Mar. . | ? | 1 | 3–5 | 7 | .. | 7 | .. | .. |
| Apr. . | 3 | .. | 5–7 | 7 | 4 | 6 | 5 | .. |
| May . | 6 | .. | 4–6 | 6 | 6 | 4 | 1 | 1 |
| June . | 3 | .. | 5–6 | 5 | 6 | 3 | 3 | .. |
| July . | .. | .. | .. | .. | .. | .. | .. | .. |
| Aug. . | 6 | .. | 6 | 2 | 2 | .. | .. | .. |
| Sept. . | 5 | .. | 7 | 4 | 1 | .. | 1 | .. |
| Oct. . | 5 | .. | 6 | 3 | 1 | .. | 6 | .. |
| Nov. . | 3 | .. | 7 | 5 | 3 | 7 | 2 | .. |

*Note.*—"Mela" includes foods such as *mahleu*, *motoho*, and others containing sprouted maize. The second figure in this column includes beer drunk on days when no other *mela* food was eaten, this differentiation being made because children do not drink beer and therefore do without *mela* food on these days.

Ordinary mealies include boiled or roasted mealies, breads, samp, and so on.

These figures indicate the number of days in the week on which food made of these materials was eaten. For greater detail regarding the types of foods eaten and the number of times a day, see Appendixes II and III.

*Family No. 2.*

| Month. | Wheat. | Green mealies. | "Mela." | Ordinary maize. | Vege-tables. | Milk. | Meat. | Eggs. |
|---|---|---|---|---|---|---|---|---|
| Dec. | .. | .. | .. | .. | .. | .. | .. | .. |
| Jan. | ? | .. | 1 ? | 7 | .. | 7 | 5 | .. |
| Feb. | 1 | 4 | 1 ? | 7 | 2 ? | 7 | .. | .. |
| Mar. | ? | 3 | 4 | 7 | 5 | 7 | .. | .. |
| Apr. | 7 | 2 | 5 | .. | 5 | 7 | .. | .. |
| May | 1 | .. | 2 | 7 | 6 | 6 | 2 | 4 |
| June | 1 | .. | 7 | 6 | 4 | 7 | 1 | 1 |
| July | .. | .. | .. | .. | .. | .. | .. | .. |
| Aug. | .. | .. | 5 | 7 | 1 | .. | .. | 1 |
| Sept. | 7 | .. | 7 | 5 | 5 | .. | .. | 2 |
| Oct. | 6 | .. | 6 | 5 | 2 | ? | 4 | 2 |
| Nov. | 7 | .. | 2–3 | 1 | 3 | 7 | 1 | .. |

*Family No. 3.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Jan. | 3 | .. | 2 | 5 | .. | 7 | .. | .. |
| Feb. | 2 | 2 | 2 | 5 | .. | 5 | .. | .. |
| Mar. | 2 | 2 | .. | 6 | 5 | 6 | .. | .. |
| Apr. | 2 | 2 | 3 | 5 | 4 | 4 | .. | .. |

*Note.*—Although Family No. 3 is recorded as having milk every day, there was enough only for one meal, and even then often only enough for the children. Family No. 2 enjoyed greater quantities of milk, as may be seen from its frequency and the variety of forms in which it was consumed (Appendixes II and III).

*Family No. 4.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dec. | .. | .. | 7 | 7 | 2 | 3 | 1 | .. |
| Jan. | .. | .. | 1 | 7 | 3 | 7 | 1 | .. |
| Feb. | .. | 1 | 1 | 7 | 3 | 7 | .. | .. |
| Mar. | .. | 2 | 1 | 7 | .. | 7 | .. | .. |
| Apr. | 4 | .. | ? | 3 ? | ? | 7 | .. | .. |

*Note.—Motoho* used by this family was unleavened, *i.e.* no *mela*.

*Family No. 5.*

| Month. | Wheat. | Green mealies. | "Mela." | Ordinary maize. | Vege-tables. | Milk. | Meat. | Eggs. |
|---|---|---|---|---|---|---|---|---|
| Dec. . | .. | .. | 5 | 7 | 3 | .. | 4 | .. |
| Jan. . | 3 | .. | 4 | 7 | 4 | .. | 2 | .. |
| Feb. . | 3 | 2 | 4 | 4 | 4 | .. | 2 | 1 |
| Mar. . | 6 | 4 | 2 | 1 | 5 | .. | .. | 1 |
| Apr. . | 7 | .. | 1 | 1 | ? | .. | 6 | .. |

*Family No. 6.*

| Month. | Wheat. | Green mealies. | "Mela." | Ordinary maize. | Vege-tables. | Milk. | Meat. | Eggs. |
|---|---|---|---|---|---|---|---|---|
| Jan. . | .. | .. | 6 | 7 | .. | .. | .. | .. |
| Feb. . | .. | 2 | .. | 7 | 2 | .. | .. | .. |
| Mar. . | .. | ? | .. | ? | ? | .. | .. | .. |

*Notes on the Preceding Families.*

No. 1. The head of this family, Mphakachane (aged about 50), is a polygamist, influential, rich in cattle and lands. He once was very rich, but now has only 50–60 cattle, over 100 sheep, and a few horses, goats, etc. He has his mother, sister, and several nephews and nieces dependent on him, besides his own wives and children.

The records refer to the household of his junior and favourite wife. For meal purposes this household consists of himself (*a*), his wife (*b*), daughter 17 years (*c*), daughter 15 (*d*), son 15 (*e*), nephew 14 (*f*).

No. 2. Head of this is nephew of the above (aged 27). His father used to be wealthy, but wealth has been dispersed through drought, theft, etc., and he has now only 18 cattle, 40 sheep, 10 goats, and 10 horses. But he has about 6 lands—as much as he can cultivate himself—and is a hard worker. He worked, before coming to me at 30s. p.m., for the local store at 10s. He has had some schooling (standard 4), and worked once as garden boy for a farmer in the Orange Free State where he learnt and became interested in gardening.

He has recently married, and his wife bore him a son in November 1935. This child is not often mentioned in the records, though most of the *motoho* recorded in the months of October and November was for him. The household consisted of the head (*a*), wife (*b*), sisters and half-sisters 18, 16, 15, 13, and half-brothers 16, 13 (Nos. *d*, *e*, *c*, *f*, *g*, *h*).

The head was also responsible for his father's second wife, *i.e.* for ploughing for and clothing her, as well as for clothing all the above.

No. 3. This was the senior living widow of the old Chief. She was about 55, had a married son of about 30 with his wife and child living with her, a younger son away at a secondary school, her brother's son of 8 years. Staying with them was the president of the Chief's court, who occasionally contributed a little food. I also had my meals with this family. The family possessed 18 cattle, 10 of which were with friends, in the village there being only 2 cows and 6 oxen. They had four fields

between them, a share of which the younger son would have to have when he married. The elder married son still owed 10 cattle on his marriage; he was a tax collector earning about 30s. p.m. When collectors came to report to the Chief, about once every two months, they were given a sheep by him to be shared out between about ten of them—the man's share of this was about the only meat the family had.

No. 4. This family consists only of a grass-widow, long since deserted by her husband, and three sons 11, 5, and a half-year old respectively. The woman was a sort of servant of the Chief's family, and had to work for them, *e.g.* grind grain, churn milk, etc. In return the Chief supported her by ploughing her two fields and giving her milk, surplus from his chief household. For clothes she depended on the money she made from beer-brewing and gifts from her lover, a man with two wives, who had been living with her for many years. As he did not always eat with her, he is shown as a guest in the records. She had no stock at all.

No. 5. The head of this family is the local teacher (40) earning about £3 a month. Whilst I was there he also got an occasional pound from me for help given. He kept records of food eaten in his house, and later when I left, in others except Nos. 1 and 2.

He had no stock at all, 100 sheep that he had had being stolen and dispersed some three years previously. He had three fields, only two being cultivated, as the third was liable to inundation.

The household consisted of his wife, sister aged 18, brother's son aged 12, and three of his own children aged 5, 3, and 1. They were puny children. He got his lands ploughed by lending out a third field (liable to be ruined by floods) to the plougher.

No. 6. This family consisted of man (aged about 40), his wife and two children, a boy of about 6 and a girl of 1. The boy was a puny child, but the girl well grown and fat. He had two other children older, but they lived with their mother's people where they should be better off.

The man had about 15 sheep and 2 horses and two lands. He had to support his mother, and during the ploughing season had to work for her, for himself, and the widow of his brother who was away at the mines. This he did with the Chief's oxen, plough, etc., after having ploughed the lands of three of his (the Chief's) households, *i.e.* he could only plough at the end of the season and so could not reap very good crops. His family never had any milk, and very occasionally were given a little meat by the Chief in return for the man's slaughtering the beasts on ritual and ceremonial occasions. (Owing to a series of unexpected deaths during the five months I was there, this happened four times.)

## APPENDIX II.

### Particulars of Foods Eaten during the Last Week of Each Month (December 1935–November 1936).

*Note* 1.—For details of these foods and the method of their preparation, see Appendix IV: Bread (*a*) is *bohobe ba lephokojoa* (*phate*); bread (*b*) is *bohobe ba linkhoa* or *ba monyahatso*.

*Family No.* 1.

| Month. | Wheat. | Maize. | | | | | | | | | | Vegetables. | | | | | | Milk. | | | | Meat. | Eggs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bread, A. | Bread, B. | Boiled maize. | Green maize. | Motoho. | Mahleu. | Lesheleshele. | Beer. | Setoto. | Mojoko. | Peas. | Beans. | Pumpkins. | Potatoes. | Spinach. | Miscellaneous. | Fresh. | Mafi. | Mofehlo. | Lehala. | | |
| Dec. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Jan. | .. | 7 | ? | 2 | .. | 1 | 7 | .. | 3 | .. | 1 | 1 | .. | .. | .. | .. | .. | 6 | .. | 6 | 1 | .. | .. |
| Feb. | 1 | 6 | ? | 1 | 1 | .. | 4 | .. | 5 | 1 | 2 | 1 | .. | .. | .. | .. | .. | 6 | 1 | 2 | 1 | 1 | .. |
| Mar. | .. | 7 | ? | .. | 1 | 3 | 3 | 1 | 4 | 1 | 1 | .. | .. | .. | .. | .. | .. | 4 | 2 | 4 | .. | .. | .. |
| Apr. | 3 | 6 | 5 | .. | .. | .. | 5 | .. | 2 | .. | 1 | 1 | .. | 1 | 2 | .. | .. | 5 | .. | 6 | 1 | 5 | .. |
| May | 6 | 1 | 5 | 1 | .. | 1 | 4 | .. | 2 | .. | 1 | 1 | 2 | 3 | 4 | 1 | .. | 4 | .. | .. | .. | 1 | 1 |
| June | 3 | 1 | 4 | 1 | .. | 3 | 2 | 1 | 5 | .. | .. | 1 | 2 | .. | 4 | 1 | .. | 3 | .. | .. | .. | 3 | .. |
| July | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Aug. | 7 | .. | .. | .. | .. | 3 | 6 | 3 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Sept. | 5 | 1 | 2 | .. | .. | 3 | 6 | 2 | 3 | 1 | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | .. |
| Oct. | 5 | 3 | 1 | .. | .. | .. | 4 | 1 | 1 | .. | 4 | 1 | .. | .. | .. | .. | .. | ? | .. | .. | .. | 6 | .. |
| Nov. | 3 | 1 | 5 | 2 | .. | 1 | 7 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | 7 | .. | .. | .. | 2 | .. |

2. One or two dishes have been omitted from these lists because they are so rarely eaten, or are eaten in such small quantities that they scarcely affect the diet save to relieve its monotony, *e.g. bohoko* (roast butterfat) or *lipabi* (roast and ground maize mixed with a little sugar).

3. Further details with regard to actual quantities of grain consumed, times of meals and foods eaten at each meal, are given in Appendix III.

4. See also note for Family No. 2.

*Family No.* 2.

| Month. | Wheat. | Maize. | | | | | | | | | | Vegetables. | | | | | | Milk. | | | | Meat. | Eggs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bread, A. | Bread, B. | Boiled maize. | Green maize. | Motoho. | Mahleu. | Lesheleshele. | Beer. | Setoto. | Mojoko. | Peas. | Beans. | Pumpkins. | Potatoes. | Spinach. | Miscellaneous. | Fresh. | Mafi. | Mofehlo. | Lehala. | | |
| Dec. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Jan. | ? | 7 | ? | .. | .. | 1 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | 2 | 1 | 7 | .. | ? | .. | 5 | .. |
| Feb. | 1 | 7 | ? | .. | 4 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | ? | 2 | 7 | 1 | 4 | 2 | .. | .. |
| Mar. | .. | 7 | .. | .. | 3 | 2 | .. | .. | .. | 1 | .. | .. | .. | 3 | .. | 1 | 2 | 4 | 2 | 4 | .. | .. | .. |
| Apr. | 7 | .. | .. | .. | 2 | 2 | 4 | .. | 1 | 1 | .. | 2 | .. | 3 | .. | .. | 1 | 7 | .. | 1 | .. | .. | .. |
| May | 1 | 6 | 1 | .. | .. | 2 | .. | .. | .. | .. | .. | 2 | 2 | 5 | .. | .. | 6 | 6 | .. | .. | .. | 2 | 4 |
| June | 1 | 3 | 3 | .. | .. | 5 | 2 | .. | 2 | .. | 1 | 2 | 1 | 1 | .. | .. | 1 | 6 | .. | .. | .. | .. | 1 |
| July | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Aug. | .. | 7 | .. | .. | .. | 6 | 1 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| Sept. | 7 | .. | .. | .. | .. | 7 | 1 | 2 | .. | 1 | .. | .. | .. | .. | .. | 4 | 2 | .. | .. | .. | .. | .. | 2 |
| Oct. | 6 | 3 | .. | .. | .. | 6 | .. | 2 | .. | .. | .. | 1 | .. | .. | .. | 1 | 1 | ? | .. | .. | .. | 5 | 2 |
| Nov. | 7 | .. | .. | .. | .. | 2 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | 3 | .. | 7 | .. | 1 | 1 | 1 | .. |

*Note.*—Although no milk was shown in the otherwise detailed records for August, September and October, the family had cattle in the village. Oxen were being used for ploughing, but cows were dry.

This also applies to Family No. 1.

### *Family No. 3.*

| Month. | Wheat. | Maize. | | | | | | | | | | Vegetables. | | | | | | Milk. | | | | Meat. | Eggs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bread, A. | Bread, B. | Boiled maize. | Green maize. | Motoho. | Mahleu. | Lesheleshele. | Beer. | Setoto. | Mojoko. | Peas. | Beans. | Pumpkins. | Potatoes. | Spinach. | Miscellaneous. | Fresh. | Mafi. | Mofehlo. | Lehala. | | |
| Jan. . | 3 | 5 | .. | .. | .. | .. | 2 | 1 | .. | 1 | .. | .. | .. | .. | .. | .. | .. | 4 | .. | 3 | .. | .. | .. |
| Feb. . | 2 | 5 | .. | .. | 2 | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 4 | .. | 3 | .. | .. | .. |
| Mar. . | 2 | 6 | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | 4 | 1 | .. | 1 | 4 | .. | 3 | .. | 2 | .. |
| Apr. . | 2 | 5 | .. | .. | 2 | .. | 2 | .. | .. | 1 | .. | .. | .. | 4 | .. | .. | .. | 4 | .. | 3 | .. | .. | .. |

### *Family No. 4.*

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec. . | .. | 6 | 2 | 3 | .. | 2 | 6 | .. | .. | .. | .. | 1 | .. | .. | .. | 1 | .. | .. | .. | 3 | .. | 1 | .. |
| Jan. . | .. | 5 | 4 | .. | .. | .. | .. | 2 | .. | 2 | .. | 1 | .. | .. | .. | 3 | .. | .. | .. | 7 | .. | 1 | .. |
| Feb. . | .. | 7 | .. | 2 | 1 | 1 | .. | .. | .. | 1 | .. | 3 | .. | 1 | .. | .. | .. | .. | .. | 7 | .. | .. | .. |
| Mar. . | .. | 7 | .. | .. | 2 | .. | 1 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 | 7 | .. | .. | .. |
| Apr. . | 4 | 3 | .. | .. | .. | 1 | .. | .. | .. | .. | .. | 2 | .. | 1 | .. | .. | .. | .. | .. | 7 | .. | .. | .. |

### *Family No. 5.*

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec. . | .. | 7 | .. | .. | .. | 3 | 5 | 1 | .. | .. | .. | .. | .. | .. | .. | 3 | .. | .. | .. | .. | .. | 4 | .. |
| Jan. . | 3 | 4 | 2 | 2 | .. | 4 | 1 | .. | .. | .. | .. | 3 | .. | .. | .. | 2 | .. | .. | .. | .. | .. | 2 | .. |
| Feb. . | 3 | 4 | .. | 2 | 1 | 1 | 3 | 2 | .. | .. | .. | .. | .. | .. | 3 | 2 | .. | .. | .. | .. | .. | 2 | 1 |
| Mar. . | 6 | 1 | .. | .. | 4 | 4 | .. | .. | 2x | .. | .. | 2 | .. | 3 | 1 | 2 | .. | .. | .. | .. | .. | .. | 1 |
| Apr. . | 7 | .. | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. | .. | ? | .. | ? | .. | .. | .. | .. | .. | 6 | .. |

2*x* stands for *leting*.

### *Family No. 6.*

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. . | .. | 7 | .. | .. | .. | 2 | 6 | .. | 1 | 1 | .. | .. | .. | .. | 2 | 2 | .. | .. | .. | .. | .. | .. | .. |
| Feb. . | .. | 7 | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. | .. |
| Mar. . | Supplies exhausted. Family living on charity of neighbours. | | | | | | | | | | | | | | | | | | | | | | |

## APPENDIX III.

The details of the diets of six families are elaborated below. Records of other families were also kept, but as they are very similar to those of the above in whose class they fall, they have not been repeated here.

Family 1 has not such an abundance of food as is to be found in the case of some of the very wealthy families, but it is typical of the type of diet to be found there. The others would probably have slightly more meat and beer, but would otherwise be very similar. Family 2 is not as well off in point of quantity of meat and cereals as Family 1, but it enjoys a relative abundance of vegetables. In this respect it is greatly in advance of the other BaSotho families I met. It will be noticed that the only other family approaching this one in this respect is the Teacher's family.

The other families are quite ordinary, although Family 4 is exceedingly lucky in its enjoyment of milk. Since I left the village the Chief's successor has removed most of the cattle to another village, and it is unlikely that this family will have as much mofehlo as heretofore.

I personally kept the records of Families Nos. 3, 5 and 6 until I left. The teacher (No. 4) kept his own all the time and then took over the other families for me for two months. Families Nos. 1 and 2 were recorded by the head of No. 2, who later (about August, taught his educated wife to keep the weights when he was away from the village).

It is regretted that the details are not more accurate and complete, but keeping even these details took up an unexpected amount of time, and as the enquiry was only an interesting sideline and not the main object of my field work, I could not give to the subject as much time as it needed and indeed deserved.

*Family No. 1.*

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| Jan. 25 | a.m. | Bread, mofehlo. | Family. |
| | noon | Bread, mofehlo, mahleu, beer. | Family. Head alone has beer. |
| | p.m. | Bread, mahleu. | Family. |
| 26 | a.m. | Bread, milk, beer. | Family. |
| | noon | Bread, milk. | Children. |
| | p.m. | Bread, milk, boiled maize, mahleu. | Family. |
| 27 | a.m. | Bread, mofehlo. | Family. |
| | noon | Bread, milk. | Children. |
| | p.m. | Bread, milk, mahleu. | Children. |
| | | Beer. | Head. |

*Note.*—This record cannot be taken to be exact, the recorder was new to the work and not getting full co-operation of the family. It is probable that occasional vegetables were eaten which are not recorded.

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| Jan. 28 | a.m. | Lehala, bread, mosoko. | Family. |
| | noon | Bread, mofehlo, mahleu. | Family. |
| | p.m. | Bread, milk, mahleu. | Family. |
| 29 | a.m. | Bread, milk. | Family. |
| | noon | Bread, mofehlo. | Children. |
| | p.m. | Bread, boiled maize, milk. | Family. |
| 30 | a.m. | Bread, milk, motoho, mahleu. | Family. |
| | noon | Bread, milk. | Children. |
| | p.m. | Bread, mofehlo, mahleu. | Family. |
| 31 | a.m. | Bread, milk, mahleu. | Family. |
| | noon | Bread, milk. | Children. |
| | p.m. | Bread, mofehlo, mahleu. | Family. |
| Feb. 23 | a.m. | Maize, bread, mofehlo. | Wife and 3 children. |
| | | Beer. | Mphakachane. |
| | noon | Bread, mofehlo. | Children. |
| | p.m. | Bread, mofehlo. | Wife and children. |
| | | Mahleu. | Mphakachane. |
| 24 | a.m. | Wheat bread, meat, milk. | Wife and children. |
| | | Meat, beer. | Mphakachane. |
| | noon | Meat, bread, mafi. | Wife and children. |
| | | Beer. | Mphakachane. |
| 25 | a.m. | Bread, milk. | Children. |
| | | Bread, milk, mahleu. | Mphakachane. |
| | noon | Bread, milk. | Children. |
| | p.m. | Bread, mofehlo, green maize. | Wife and children. |
| | | Lekoele. | Mphakachane. |
| 26 | a.m. | Bread, milk. | All. |
| | noon | Bread, milk. | All. |
| | p.m. | Bread, whey, pumpkin, and setoto. | All. |
| 27 | a.m. | Bread, milk, boiled maize, mahleu. | All. |
| | noon | Bread, milk, lehala. | Children. |
| | p.m. | Bread, milk. | Wife and children. |
| | | Beer. | Mphakachane and friends. |
| 28 | a.m. | Bread, milk, mosoko. | Wife and children. |
| | | Beer. | Mphakachane and friends. |
| | noon | Bread, beer, mosoko. | Wife and children. |
| | | Beer. | Mphakachane and more friends. |

*Note.*—Children above includes the head's wife, translation of inclusive term *bana*.

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| Feb. 28 | p.m. | Bread, milk. | Wife and children. |
| | | Beer. | Mphakachane and friends. |
| 29 | a.m. | Bread, milk, mosoko. | Wife and children. |
| | | Beer. | Mphakachane and friends. |
| | noon | Bread, milk, mahleu. | Family. |
| | p.m. | Bread, milk, mahleu, beer. | Family and friends. |
| Mar. 25 | a.m. | Bread, motoho, milk. | Children. |
| | | Beer. | Head and friend. |
| | noon | Bread, motoho, mahleu. | Children. |
| | p.m. | Bread, bohoko. | Children. |
| | | Beer. | Head. |
| 26 | a.m. | Bread, milk, mahleu. | Children. |
| | | Beer. | Head. |
| | noon | Bread, mofehlo. | Children. |
| | p.m. | ? ? | ? |
| 27 | a.m. | Bread, milk. | Children. |
| | | Bread, lekoele. | Head. |
| | noon | Bread, mofehlo. | Children. |
| | p.m. | Bread, mofehlo, lekoele. | Family. |
| 28 | a.m. | Bread, motoho. | Children. |
| | | Bread, lekoele. | Head and friend. |
| | noon | Bread, setoto. | Children. |
| | | Bread, lekoele. | Head and friend. |
| | p.m. | ? ? | ? |
| 29 | a.m. | Bread, mafi. | Family. |
| | noon | Bread, mofehlo. | Children. |
| | p.m. | Bread, mofehlo, green maize. | Family. |
| 30 | a.m. | Bread, milk, lesheleshele. | Children. |
| | noon | Beer. | Head. |
| | p.m. | Bread, milk. | Children. |
| | | Beer. | Head. |
| 31 | a.m. | Bread, mofehlo. | Children. |
| | | Beer. | Head. |
| | noon | Motoho. | Children. |
| | p.m. | Bread, mafi, mahleu. | Children. |
| | | Beer. | Head. |
| Apr. 24 | a.m. | Bread (*a*), meat, milk. | Family. |
| | noon | Bread, gravy, mahleu. | Family. |
| | 7 p.m. | Bread (*b*), mofehlo, gravy, mahleu. | Family. |
| 25 | 9 a.m. | Bread (*a*), milk, mahleu. | Family. |
| | noon | Bread (*b*), mahleu. | Family. |
| | 8 p.m. | Bread (*a*), mofehlo, pumpkin. | Family. |

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| Apr. 26 | 7.30 a.m. | Bread (*a*), meat, mofehlo, beer. | Family. |
| | noon | Beer. | Head and friends. |
| | 7 p.m. | Wheat, bread, meat. | Wife and children. |
| | | Wheat, bread, meat, beer. | Head and friends. |
| 27 | 8 a.m. | Bread (*a*), meat, mofehlo. | Wife and children. |
| | noon | Bread (*a*), meat, mofehlo. | Wife and children. |
| | 7 p.m. | Bread (*b*), meat, milk. | Wife and children. |
| | | Beer. | Head (all day). |
| 28 | 9 a.m. | Wheat bread, meat, potatoes. | Family. |
| | | Wheat bread, mahleu. | 3 guests. |
| | noon | Bread (*a*), lehala. | Children. |
| | | Mahleu. | Head. |
| | 7.30 p.m. | Wheat bread, mofehlo. | Family. |
| 29 | 8.30 a.m. | Bread (*a*), milk. | Wife and children. |
| | | Potatoes, mahleu. | Head. |
| | noon | Bread (*b*), milk. | Children. |
| | 7 p.m. | Bread (*b*), potatoes, mosoko, peas. | Family. |
| 30 | 9 a.m. | Bread (*b*), milk, meat, mahleu. | Family. |
| | noon | Bread (*b*), gravy. | Children. |
| | 7 p.m. | Wheat bread, mofehlo, mahleu. | Family. |
| May 25 | 8 a.m. | Bread (*a*), potatoes, gravy, mahleu, pumpkin. | No details given except for those shown below. |
| | 1 p.m. | Bread (*a*), bohoko. | |
| | 6.30 p.m. | Bread (*b*), pumpkin, potatoes, mahleu. | |
| 26 | 9 a.m. | Wheat bread, pumpkin, roasted maize, mahleu. | |
| | 2 p.m. | Roasted maize. | |
| | 6 p.m. | Bread (*b*), beans, mahleu. | |
| 27 | 8 a.m. | Bread (*b*), roasted maize, beans, pumpkin. | |
| | 1 p.m. | Wheat bread, beans. | |
| | 5.30 p.m. | Wheat bread, milk, spinach (pumpkin leaves), bohoko. | |
| 28 | 10 a.m. | Wheat bread, milk, mahleu. | |
| | 2 p.m. | Boiled maize. | |
| | 6 p.m. | Wheat bread, boiled maize, mahleu, eggs. | |
| 29 | 10 a.m. | Wheat bread, mahleu, motoho. | |

*Note.*—When there was beer or *mahleu* available, the head relied on them for food more than on other dishes. Occasionally, such as on April 27, he had only beer the whole day.

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| May 29 | 2 p.m. | Wheat bread. | |
| | 7.30 p.m. | Wheat bread, chicken, potatoes. | |
| 30 | 9 a.m. | Bread (*b*), milk, beer. | |
| | 2 p.m. | Bread (*b*), milk, beer. | Beer shared with the head's friends; come to help to tan a skin. |
| | 6.30 p.m. | Wheat bread, peas, potatoes, beer. | |
| 31 | 10.30 a.m. | Wheat bread, mosoko, potatoes. | |
| | 6.30 p.m. | Bread (*b*), milk, mosoko, beer. | |
| June 24 | 9.30 a.m. | Bread (*b*), motoho, milk. | Family. |
| | | Beer. | Head. |
| | 11 a.m. | Beer. | Being sold. |
| | 3 p.m. | Beer. | Head and 4 friends. |
| | 6 p.m. | Bread (*a*), beans, beer. | Family. |
| 25 | 8.30 a.m. | Bread (*b*), meat, milk, potatoes. | Family. |
| | 9 a.m. | Beer. | Head and 2 friends. |
| | 11 a.m. | Beer. | Head and 4 friends. |
| | 2.30 p.m. | Milk, bread (*b*), mahleu, meat. | Children. |
| | p.m. | Lesheleshele, bread (*b*), meat, milk, mahleu. | Family. |
| | | Beer. | Head and 2 friends. |
| 26 | 9.30 a.m. | Wheat bread, potatoes, meat, beer. | Family. |
| | noon | Motoho. | Children. |
| | | Beer. | Head. |
| | 5.30 p.m. | Wheat bread, meat, potatoes, beer. | Family. |
| 27 | 7 a.m. | Beer. | Head and 2 friends. |
| | 9 a.m. | Bread (*b*), peas, milk. | Wife and children. |
| | 11 a.m. | Beer. | Head and friends. |
| | 2.30 p.m. | Beer. | Head and friends. |
| | | Bread (*b*), peas, pumpkin, motoho. | Children. |
| | 6.30 p.m. | Bread (*b*), peas, milk. | Family. |
| 28 | 8.30 a.m. | Wheat bread, maize, stamp, gravy. | Family. |
| | 11 a.m. | Meat. | Head with friends. |
| | 3 p.m. | Wheat, bread. | Children. |
| | 5.30 p.m. | Meat, beans, potatoes. | Family. |
| 29 | 8.30 a.m. | Bread (*b*), meat. | Family. |

| Date | Time. | Food. | Consumers. |
|---|---|---|---|
| June 29 | 10 a.m. | Mahleu. | Head. |
| | 1.30 p.m. | Mahleu. | Head. |
| | 5.30 p.m. | Bread (*b*), gravy. | Family. |
| 30 | 9 a.m. | Wheat bread, beer. | Family. |
| | 10 a.m. | Beer. | Head. |
| | 2 p.m. | Wheat bread. | Children. |
| | 6 p.m. | Wheat bread, potatoes, beer. | Family. |

| Date. | Time. | Food. | Weight. | | Consumers. |
|---|---|---|---|---|---|
| | | | | lbs. | |
| Aug. 25 | 8 a.m. | Mahleu, no details of bread. | K. corn, | 8½ | |
| | | | Maize, | 5½ | |
| | 4 p.m. | Wheat bread. | Wheat, | 8 | |
| 26 | 8 a.m. | Wheat bread. | Wheat, | 15 | |
| 27 | 9 a.m. | Wheat bread. | Wheat, | 12½ | |
| | | Mahleu. | Maize, | 10 | |
| | | Lesheleshele. | Maize, | 5 | |
| | 6 p.m. | Wheat bread. | Wheat, | 16½ | |
| 28 | 5 p.m. | Mahleu. | Maize, | 9 | |
| | | Wheat bread. | Wheat, | 8½ | |
| 29 | 7 a.m. | Boiled peas. | Peas, | 8½ | |
| | 5 p.m. | Lesheleshele. | Maize, | 3 | |
| | | Motoho. | Maize, | 6 | |
| 30 | .. | Nothing fresh cooked. | | | |
| 31 | 8.30 a.m. | Wheat bread. | Wheat, | 5½ | |
| | | Mahleu. | Mabela, | 3½ | |
| | | Mela. | Wheat, | 2½ | |
| | 5 p.m. | Motoho. | Maize, | 4 | |
| | | Lesheleshele. | Maize, | 2½ | |

Summary:

| | |
|---|---|
| Maize . . . . . . | 45 lbs. |
| Wheat . . . . . . | 68½ lbs. |
| Mabele . . . . . . | 12 lbs. |
| Peas . . . . . . | 8½ lbs. |

Consumers the same as usual, so far as I know.
Milk still available, though not specifically stated.

| | | | | | |
|---|---|---|---|---|---|
| Sept. 24 | 9 a.m. | Wheat bread, lesheleshele, chicken. | Maize, | 2 | *a*, *b*, *c*, *d*. |
| | | | Wheat | 5 | |
| | noon | Wheat bread. | Maize, | 18½ | *c*. |
| | | Beer | .. | | *a*, *b*. |
| | 7 p.m. | Beer. | .. | | *a*. |
| | | Wheat bread, motoho. | Maize, | 6½ | *a*, *d*, and guest; *b* gone to ceremony. |
| 25 | 7.30 a.m. | Wheat bread. | Wheat, | 11 | *b*, *c*, *d*. |
| | | Beer. | .. | | *a*. |
| | 11 a.m. | Beer. | .. | | *a* and guest. |
| | 2 p.m. | Wheat bread. | .. | | *b*, *c*. |
| | 6 p.m. | Wheat bread, mahleu. | Maize, | 6 | *b*, *c*, *d*. |
| | | Beer. | .. | | *a* and 2 guests. |

| Date. | Time. | Food. | Weight. | | Consumers. |
|---|---|---|---|---|---|
| | | | | lbs. | |
| Sept. 26 | 8.30 a.m. | Wheat bread, mahleu, moroko. | .. | | *a, b, c.* |
| | | Moroko. | .. | | 2 guests. |
| | 11 a.m. | Mahleu, moroko. | .. | | *a* and guest come to buy 10 trees at 2s. 6d. |
| | 2 p.m. | Wheat bread. | .. | | *b, c.* |
| | 6.30 p.m. | Motoho, mahleu. | Maize,<br>Maize, | 6½<br>9 | *a, b, c, d, f.* |
| 27 | 9 a.m. | Maize bread (*b*), motoho, mahleu. | Maize, | 7½ | *a, b, c, d.* |
| | 1 p.m. | Mahleu. | .. | | *a* and guest. |
| | 2 p.m. | Mahleu. | .. | | *a, b.* |
| | | Bread (*b*), notoho. | .. | | *c* and 3 girl guests. |
| | 6.30 p.m. | Bread (*b*), mahleu, motoho. | .. | | *a, b, c, d.* |
| 28 | 10 a.m. | Bread (*b*), mahleu. | .. | | *a, b, c, d.* |
| | 1 p.m. | Bread (*b*), mahleu. | .. | | *a, b, c.* |
| | 4.30 p.m. | Mahleu. | .. | | *a* and friend. |
| | 6.30 p.m. | Bread (*b*), mahleu. | .. | | *a, b, c, d.* |
| 29 | 9.30 a.m. | Wheat bread, mahleu. | Wheat,<br>Maize, | 15<br>9 | *a, b, c, d.* |
| | 11 a.m. | Wheat bread. | Maize, | 12½ | *c* and friend. |
| | 3 p.m. | Beer. | .. | | *a* and 2 friends. |
| | 8 p.m. | Wheat bread. | .. | | *a, b, c, d.* |
| | | Beer. | .. | | *a, b.* |
| 30 | 9.30 a.m. | Wheat bread, lesheleshele, mahleu. | Wheat,<br>Maize, | 7½<br>4½ | *a, b, c, d* and 2 friends. |
| | noon | Wheat bread, lesheleshele, mahleu. | .. | | *c, e* and 2 friends. |
| | 1.30 p.m. | Lesheleshele, setoto. | .. | | *c* and 2 friends. |
| | 4.30 p.m. | Wheat bread. | .. | | 2 friends. |
| | 7 p.m. | Bread (*a*), lesheleshele, peas. | Maize,<br>Peas | 4<br>5 | *b, c, d, e* and 2 friends. |
| | Summary: | | | | |
| | | Maize . . . . . . | 86 lbs. | | |
| | | Wheat . . . . . . | 38½ lbs. | | |
| | | Peas . . . . . . | 5 lbs. | | |
| Oct. 25 | 9 a.m. | Bread (*b*), peas, moroko. | Meal,<br>Peas, | 3<br>17 | Family. |
| | 2 p.m. | Lesheleshele, mahleu. | Meal, | 2 | Wife and 2 friends. |
| | 5 p.m. | Bread (*a*), mahleu, peas. | Meal, | 5 | *a, b, c, f,* and guest, 15 years. |
| 26 | 7.30 a.m. | Beer. | .. | | *a, b.* |
| | 9 a.m. | Wheat bread, meat (beef). | Wheat,<br>Meat, | 9<br>7 | *b, c, d, e.* |
| | 4 p.m. | Beer, moroko. | .. | | *a* and 3 friends. |
| | 6.30 p.m. | Wheat bread, meat. | .. | | *c, d, e, f,* and guest, 15 years. |
| | | Mosoko. | .. | | *b.* |
| | | Beer. | .. | | *a.* |
| 27 | 7.30 a.m. | Moroko. | .. | | *a* and 3 friends. |
| | 9 a.m. | Wheat bread, beef. | Wheat,<br>Meat, | 12<br>? | *a, b, c, d.* |
| | noon | Wheat bread. | .. | | *c, d.* |
| | p.m. | Wheat bread, beef, moroko. | .. | | *a, b, c, d, e.* |

| Date. | Time. | Food. | Weight. | | Consumers. |
|---|---|---|---|---|---|
| | | | | lbs. | |
| Oct. 28 | 8.30 a.m. | Bread (*a*), beef, moroko. | Meal, | 9 | *a*, *b*, *c*, *e*. |
| | | | Meat, | 9 | |
| | 10 a.m. | Mahleu. | .. | | *a* and friends. |
| | 1 p.m. | Wheat bread, beef, mahleu. | .. | | *a*, *b*, *e*, and 2 guests (adults). |
| | 3 p.m. | Wheat bread. | .. | | *c*, *d*. |
| | 7 p.m. | Wheat bread, mahleu, beef. | .. | | *a*, *b*, *c*, *d*, *e*, *f*. |
| 29 | 8.30 a.m. | Wheat bread, beef, mahleu. | Wheat, | 10 | *a*, *b*, *c*, *d*, *e*. |
| | | | Meat, | 9 | |
| | 1 p.m. | Wheat bread, beef. | .. | | *d*, *f*. |
| | 2 p.m. | Mahleu. | .. | | *a* and friend. |
| | 7 p.m. | Wheat bread, beef, spinach. | .. | | *a*, *b*, *c*, *d*, *e*. |
| 30 | 9 a.m. | Bread (*a*), beef. | Meal, | 5 | *a*, *b*, *c*, *d*, *e*. |
| | | | Meat, | 18 | |
| | 1 p.m. | Bread (*a*), meat. | .. | | *a*, *b*, *e*, |
| | 2.30 p.m. | Bread (*a*), meat. | .. | | *c*, *d*, *f*. |
| | 6.30 p.m. | Bread (*a*), meat. | Meal, | 4 | *a*, *b*, *c*, *d*, *e*, *f*. |
| 31 | 8.30 a.m. | Wheat bread, meat, mahleu. | Wheat, | 6 | *a*, *b*, *c*, *e*. |
| | 10 a.m. | Mahleu. | .. | | *a*. |
| | 1 p.m. | Wheat bread, meat. | .. | | *c*, *d*, *e*. |
| | 3 p.m. | Beef, mahleu. | .. | | *a* and 2 friends. |
| | 6.30 p.m. | Wheat, bread, meat. | .. | | *a*, *b*, *c*, *d*, *e*, *f*. |

Summary of quantities:

Maize . . . 28 lbs.—excluding amounts for mahleu and beef.
Wheat . . . 37 lbs.
Peas . . . 17 lbs.
Meat . . . 43 lbs.—probably more actually consumed.

| Date. | Time. | Food. | Weight. | | Consumers. |
|---|---|---|---|---|---|
| Nov. 24 | 7 a.m. | Bread (*b*), motoho, milk, spinach and mahleu. | Br. meal, | 3 | *a*, *b*, *c*, *d*, *e*, *f*. |
| | | | Mo. meal, | 7 | |
| | 1 p.m. | Bread (*b*), milk, mahleu. | .. | | *b*, *d*, *e*, *f*. |
| | 7 p.m. | Bread (*b*), boiled maize, milk. | Br. meal, | 4 | *b*, *c*, *d*, *e*, *f*. |
| | | | Maize, | 6 | |
| 25 | 8.30 a.m. | Wheat bread, milk, boiled maize and mahleu. | Wheat, | 11 | *a*, *b*, *d*, *e*, *f*. |
| | 1 p.m. | Wheat bread, mutton, mahleu. | .. | | *a* and 2 friends. |
| | 5 p.m. | Wheat bread, milk. | .. | | *b*, *d*. |
| | 7 p.m. | Wheat bread, meat, milk. | .. | | *a*, *b*, *d*, *e*, *f*. |
| 26 | 7 a.m. | Bread (*a*), meat. | Meal, | 8 | *a*, *b*, *d*, *e*, *f*. |
| | | | Meat, | 4 | |
| | 1 p.m. | Bread (*a*), meat, milk, mahleu. | .. | | *a* and 4 friends. |
| | 7 p.m. | Bread (*b*), meat, onions, mahleu. | Meal, | 6 | *a*, *b*, *d*, *e*, *f*. |
| | | | Meat, | 5 | |
| 27 | 7 a.m. | Bread (*b*), milk, mahleu. | Meal, *f*. Mahleu | 5 | *a*, *b*, *c*, *e*, *f*. |
| | 2 p.m. | Bread (*b*), milk, mahleu. | .. | | *a*, *f*. |
| | 3 p.m. | Bread, milk. | Meal, | 9 | *d*, *e*, *f*. |
| | 6.30 p.m. | Bread (*b*), milk, mahleu. | .. | | *a*, *b*, *d*, *e*, *f*. |
| 28 | 8.30 a.m. | Bread (*b*), spinach. | .. | | *a*, *d*, *e*, *f*, *b*. |
| | 1.30 p.m. | Wheat bread, milk, mahleu. | Wheat, | 11 | *a*, *b*, *d*, *f*. |
| | 6.30 p.m. | Wheat bread, mahleu. | Meal, *f*. Mahleu | 10 | *a*, *b*, *d*, *e*, *f*. |
| 29 | 8 a.m. | Wheat bread, mahleu, milk. | .. | | *a*, *b*, *d*, *e*, *f*. |
| | 1.30 p.m. | Wheat bread, mahleu, milk. | .. | | *a*, *b*, *d*, *f* (*b*, *d* at fields). |

| Date. | Time. | Food. | Weight. | Consumer. |
|---|---|---|---|---|
| Nov. 29 | 7 p.m. | Wheat bread, mahleu, milk. | .. | *a, b, d, e, f.* |
| 30 | 8 a.m. | Bread (*b*), mahleu. | Br. meal, 18<br>Meal, *f*, 7<br>Mahleu | *a, b, d, e, f.* |
| | 11.30 a.m. | Bread, milk. | .. | *f* and friend. |
| | 3 p.m. | Bread (*b*), milk, mahleu. | .. | *a, f* (*b, d* at fields). |
| | 7.30 p.m. | Bread (*b*), milk, mahleu. | Meal, 3 | *a, b, d, e, f,* and guest. |

Summary of quantities:

| | |
|---|---|
| Maize for bread . . . | 41 lbs. |
| Maize for mahleu . . | 22 lbs. (plus unweighed amount for Nov. 24–26). |
| Maize for motoho . . | 7 lbs. |
| Maize (boiled) . . . | 6 lbs. |
| Total . . | 76 lbs. |
| Wheat . . . . . | 22 lbs. |
| Meat . . . . . . | 9 lbs. |

*Family No. 2.*

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| Jan. 25 | a.m. | Bread, sugar, milk. | |
| | noon | Bread, milk. | |
| | p.m. | ? | |
| 26 | a.m. | Bread, meat, milk. | |
| | noon | ? | |
| | p.m. | Bread, meat, gravy. | |
| 27 | a.m. | Bread, meat, gravy. | |
| | noon | Bread, milk. | |
| | p.m. | Bread, meat, milk. | |
| 28 | a.m. | Bread, meat, gravy, milk. | |
| | noon | Bread, milk. | |
| | p.m. | Bread, meat, gravy. | |
| 29 | a.m. | Bread, meat, milk. | |
| | noon | Bread, milk. | |
| | p.m. | Bread, meat, milk. | |
| 30 | a.m. | Bread, meat. | |
| | noon | ? | |
| | p.m. | Bread, milk. | |
| 31 | a.m. | Bread, motoho, milk. | |
| | noon | Bread, milk. | |
| | p.m. | Bread, stamp, milk. | |

*Note.*—Although several dishes are recorded for the same meal, this does not mean that everyone at the meal had all of them. *E.g.* the last meal—some may have had bread and stamp, others bread and milk. As the record is not quite complete, I have not thought it worth while including the few details there are on this point.

| Date. | Time | Food. | Consumers. |
|---|---|---|---|
| Feb. 23 | a.m. | Bread, mofehlo. | Family. |
| | noon | Bread, mofehlo. | Children. |
| | p.m. | Bread, mofehlo, green mealies. | Family. |
| 24 | a.m. | Bread, mofehlo, green mealies. | Family. |
| | noon | Bread, mofehlo. | 2 children. |
| | p.m. | Bread, lehala. | Family. |
| 25 | a.m. | Lehala, sweets. | Family. |
| | noon | Bread, mofehlo. | 2 children. |
| | p.m. | Bread, mofehlo. | Family. |
| 26 | a.m. | Bread, mofehlo. | Head and 5 children. |
| | | Bread, milk. | 2 children. |
| | noon | Bread, mofehlo. | 1 child. |
| | 3 p.m. | Bread, mofehlo. | Other children. |
| | p.m. | Bread, milk, green mealies. | Family. |
| 27 | a.m. | Bread, whey, green mealies, peaches. | Family. |
| | noon | Bread, milk, green mealies. | 1 child. |
| | p.m. | Bread, milk. | Family. |
| Feb. 28 | a.m. | Bread, milk, peaches. | Family. |
| | noon | Bread, milk. | 1 child. |
| | p.m. | Bread, milk. | Family. |
| | | Mosoko. | 2 children (as well). |
| 29 | a.m. | Bread, mafi. | Family. |
| | noon | Wheat, bread, mafi. | 2 children. |
| | p.m. | Wheat, bread, milk. | Family. |
| Mar. 25 | a.m. | Bread, mofehlo. | Family. |
| | noon | Bread, mofehlo, green mealies, | Family. |
| | p.m. | Bread, motoho, green mealies, milk. | Family. |
| 26 | a.m. | Bread, milk, green mealies. | Family. |
| | noon | ? | ? |
| | p.m. | Bread, milk. | Family. |
| 27 | a.m. | Bread, whey, spinach. | Family. |
| | noon | Bread, motoho. | 2 children. |
| | p.m. | Bread, milk, spinach. | Family. |
| 28 | a.m. | Bread, mafi. | Family head and 1 child. |
| | noon | Bread, setoto. | Other children. |
| | p.m. | Bread, setoto. | Head. |
| | p.m. | Bread, setoto, pumpkin, milk. | Rest of family. |
| 29 | a.m. | Bread, pumpkin, mofehlo. | Family. |
| | noon | ? | ? |
| | p.m. | Bread, mofehlo. | Family. |

*Note.*—The two children usually away from home at midday are the two lads of the family who are herdboys. They dig for themselves occasional wild roots, or gather what few berries or edible leaves there are.

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| Mar. 30 | a.m. | Bread, mafi. | Head—rest of family later. |
| | noon | Bread, mofehlo. | 2 children. |
| | p.m. | Bread, mofehlo, pumpkin, green mealies. | Children. |
| | | Bread, bohoko. | Head. |
| 31 | a.m. | Bread, mofehlo. | Family. |
| | noon | Mosoko. | 3 children. |
| | p.m. | Bread, mosoko, mofehlo. | Family. |
| Apr. 24 | 9 a.m. | Wheat bread, milk. | Family. |
| | noon | Wheat bread. | Mother and 1 child. |
| | 7 p.m. | Wheat bread, milk. | Family. |
| 25 | 8 a.m. | Wheat bread, green mealies, motoho and bohoko. | Family. |
| | noon | Wheat bread, milk. | Family, less 2 children. |
| | 7 p.m. | Wheat bread, milk, pumpkin. | Family. |
| 26 | 7.30 a.m. | Wheat bread, whey, setoto, mahleu. | Family. |
| | noon | Wheat bread, peas. | 4 children. |
| | 6 p.m. | Wheat bread, whey, green mealies, mahleu. | Family. |
| 27 | 7.30 a.m. | Wheat bread, peas, milk. | Family. |
| | 10 a.m. | Wheat bread, mofehlo. | Mother. |
| | noon | Wheat bread, mofehlo, peas. | Family, less 2 children. |
| | 7 p.m. | Wheat bread, milk, cabbage. | Family. |
| 28 | 8 a.m. | Wheat bread, milk, motoho and mahleu. | Family. |
| | 12.30 p.m. | Wheat bread, milk. | Family. |
| | p.m. | ? | ? |
| 29 | 9 a.m. | Wheat bread, milk, pumpkin. | Family. |
| | 1.30 p.m. | Wheat bread, milk. | Mother and 3 children. |
| | | Beer. | Visitors. |
| | 8 p.m. | Wheat bread, milk, mahleu. | Family. |
| 30 | 8.30 a.m. | Wheat bread, milk, pumpkin. | Family. |
| | 2.30 p.m. | Wheat bread, milk. | 2 children. |
| | 7 p.m. | Wheat bread, milk, pumpkin and mahleu. | Family. |
| May 25 | 9.15 a.m. | Bread (*a*), chicken, cabbage, kohlrabi. | Family. |
| | noon | Motoho, cabbage, kohlrabi. | 2 children. |
| | 6 p.m. | Bread (*a*), cabbage, kohlrabi, beans and pumpkin. | Family. |

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| May 26 | 8.30 a.m. | Bread (*a*), milk, sugar. | Family. |
| | | Eggs, butter. | Head and wife. |
| | noon | Nil. | Nil. |
| | 6 p.m. | Bread (*a*), milk. | Family. |
| 27 | 9.40 a.m. | Bread (*a*), milk, kohlrabi. | Family. |
| | noon | Nil. | Nil. |
| | 6 p.m. | Bread (*a*), milk, pumpkin, beans and carrots. | Family. |
| 28 | 8 a.m. | Bread (*a*), milk. | Family. |
| | 11 a.m. | Motoho. | 2 children. |
| | 6 p.m. | Bread (*a*), milk, pumpkin, kohlrabi, cabbage, chicken and eggs. | Family (eggs only for parents). |
| 29 | 10.30 a.m. | Bread (*a*), milk, pumpkin, kohlrabi and cabbage. | Family. |
| | noon | Bread (*a*), pumpkin. | 2 children. |
| | 5.30 p.m. | Bread (*a*), milk, mahleu, sugar. | Family. |
| | | Eggs. | Parents. |
| 30 | 9 a.m. | Bread (*a*), milk, peas, cabbage, | Family. |
| | 2 p.m. | Bread (*a*). | 2 children. |
| | 7 p.m. | Bread (*a*), milk, peas, kohlrabi. | Family. |
| 31 | 8.30 a.m. | Bread (*b*), roast maize, kohlrabi, peas, cabbage, pumpkin. | Family. |
| | 11.40 a.m. | Mabele bread, milk. | Mother and 2 children. |
| | 8.30 p.m. | Bread (*b*), milk, roast maize, eggs. | Family (eggs only for parents). |
| June 21 | 8 a.m. | Bread (*a*), motoho, milk, mosoko, kohlrabi. | Family. |
| | noon | Bread (*a*), milk. | 1 child. |
| | 12.45 p.m. | Beans. | Mother and children. |
| | 6 p.m. | Bread (*b*), mosoko, milk, beans, eggs. | Family (eggs for parents and 1 child). |
| 22 | 8.30 a.m. | Bread (*b*), milk. | . . |
| | | Beer, bread (*b*), mahleu, motoho. | Work party. |
| | 11 a.m. | Bread (*b*). | 2 children. |
| | 3 p.m. | Bread (*b*), peas. | Children. |
| | 6 p.m. | Bread (*b*), peas, milk. | Family. |
| 23 | 8.30 a.m. | Beer. | Visitors. |
| | 9 a.m. | Wheat bread, motoho, meat. | Family and 4 guests. |
| | 2 p.m. | Wheat bread, meat. | Family and 4 other guests. |
| | 7 p.m. | Wheat bread, meat, beer. | Family. |

| Date. | Time. | Food. | Consumers. |
|---|---|---|---|
| June 24 | 9 a.m. | Bread (*a*), milk. | Family. |
| | 1.30 p.m. | Bread (*a*), motoho. | 2 children. |
| | 5.30 p.m. | Bread (*a*), milk, motoho. | Family. |
| 25 | 8.30 a.m. | Motoho, milk. | Family. |
| | 1 p.m. | Moto, milk. | Mother and 1 child. |
| | 2.15 p.m. | Motoho. | Other children. |
| | 5.30 p.m. | Bread (*a*), milk. | Family and guest. |
| 26 | 9 a.m. | Bread (*b*), milk, motoho. | Family. |
| | 1.30 p.m. | Motoho, milk. | Mother and 1 child. |
| | 6 p.m. | Bread (*b*), peas, pumpkin, mahleu. | Family. |
| 27 | 9.30 a.m.* | Bread (*b*), milk, kohlrabi, cabbage. | Family. |
| | noon | Bread (*b*), motoho. | Mother and children. |
| | 5.30 p.m. | Bread, milk, khoalhla, mosoko. | Family. |

* By informant that this bread made out of yellow maize.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Aug. 25 | 8 a.m. | Bread (*a*). | Mealie meal, 4½ | |
| | 5 p.m. | Bread (*a*), eggs. | Mealie meal, 4½ | |
| 26 | 8.30 a.m. | Fermented motoho. | Mealie meal, 2½ | |
| | | Unfermented motoho (for babe). | Mealie meal, 4½ | |
| | 5 p.m. | Fermented motoho. | Mealie meal, 2½ | |
| | | Bread (*b*). | Mealie meal, 9 | |
| 27 | 8.30 a.m. | Maize bread (*a*). | Mealie meal, 4½ | |
| | | Unfermented motoho (for babe). | Mealie meal, 2 | |
| 28 | 7.30 a.m. | Bread (*a*). | Mealie meal, 5 | |
| | | Motoho. | Mealie meal, 5 | |
| | 6 p.m. | Motoho. | Mealie meal, 6 | |
| 29 | 6 p.m. | Bread (*a*). | Mealie meal, 7½ | |
| | | Motoho (for babe). | Mealie meal, 2½ | |
| 30 | .. | (Nothing cooked.) | | |
| 31 | 8.30 a.m. | Bread (*a*). | Mealie meal, 4 | |
| | | Peas. | 2 | |
| | 5 p.m. | Motoho. | Mealie meal, 3 | |
| | | Motoho (for babe). | Mealie meal, 1 | |
| | | Mahleu. | Mealie meal, 4½ | |

Summary:
Maize . . . . . . 772½ lbs.
Peas . . . . . . 2 lbs.

*Note by Informant.*—"So much bread (*a*)—*bohobe ba lephoko joa*—being cooked because we are faced by famine. The position is serious. We got nothing from the fields at harvest-time.* In June I had to buy £2 worth of grain and I shall now have to buy more. We, my children will suffer for the next three months; but if we have rain oats and peas should be ripe by December, and we will be able to exchange them for grain." (*Note.* £2 worth of grain should have been about 4 bags.)

*Obs.*—Only the above data were given. In addition to the above, milk was probably still obtainable. The consumers were, so far as I know, the same as before.

* See Appendix V.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Sept. 24 | 8.30 a.m. | Wheat bread, motoho. | Wheat, 5<br>Maize, 6 | *a, b, c, d, e, f, g, h.* |
| | 1 p.m. | Wheat bread, motoho. | Maize, 5½ | *c* and babe. |
| | 2 p.m. | Lesheleshele. | .. | *b, c, d,* and girl friend. |
| | 7 p.m. | Wheat bread, motoho, onions. | Wheat, 6½ | *a, b, c, d, e, f, g, h.* |
| 25 | 9 a.m. | Wheat bread. | Wheat, 5½ | *d, e, f, g, h.* |
| | | Wheat bread, motoho, egg, d. | .. | *a, b, c,* and babe. |
| | noon | Wheat bread, motoho. | .. | *b, c, d,* and babe. |
| | 2.30 p.m. | Lesheleshele. | Maize, 2½ for this. | *e, f, g, h.* |
| | 7.30 p.m. | Wheat bread, motoho, spinach. | Wheat, 6½ | *a, b, c, d, e, f, g,* babe. |
| 26 | 7 a.m. | Wheat bread. | Wheat, 5 | *a, b, c, d, e, f, g.* |
| | | Motoho. | .. | Babe. |
| | 2 p.m. | Lesheleshele. | Maize, ? | *b, c, d, e, f.* |
| | 6 p.m. | Wheat bread, motoho. | Maize, 5 | *a, b, c, d, e, f, g,* babe. |
| 27 | 10 a.m. | Wheat bread, motoho. | Wheat, ? | *a, b, c, d, e, f, g,* babe. |
| | noon | Wheat bread, motoho. | .. | *c, d, e, f.* |
| | 1.30 p.m. | Motoho. | .. | Guest. |
| | 4.30 p.m. | Wheat bread, motoho. | .. | *a, b.* |
| | 7 p.m. | Wheat bread, spinach, onions. | .. | *a, b, c, d, e, f, g.* |
| 28 | 9 a.m. | Wheat bread. | .. | *a, b, c, d, e, f.* |
| | | Motoho. | .. | Babe. |
| | noon | Motoho. | .. | *b, c.* |
| | 2 p.m. | Wheat bread, samp. | Maize, 6 | *b, c, d, e, f,* babe. |
| | 6.30 p.m. | Wheat bread, motoho. | Wheat, 4½ | *a, b, c, d, e, f, g, h,* babe. |
| 29 | 9 a.m. | Wheat bread, samp, motoho. | Wheat, 4½ | *a, b, c, d, e, f,* babe; *g, h* elsewhere. |
| | 11 a.m. | Motoho. | .. | *b,* babe. |
| | 1.30 p.m. | Wheat bread. | .. | *c, d.* |
| | 7.30 p.m. | Wheat bread, spinach, | Wheat, 5½ | *a, b, c, d, e, f, g, h.* |
| | | Motoho. | .. | Babe. |
| 30 | 8.30 a.m. | Wheat bread, mahleu. | Wheat, 8<br>Maize, 4 | *a, b, c, d, e, f.* |
| | 7.30 p.m. | Motoho. | .. | Babe. |
| | 10 p.m. | Wheat bread, mahleu. | Maize, 4½ | *g* and 3 guests. |
| | 2.30 p.m. | Motoho, egg. | .. | Babe. |
| | 4 p.m.* | Setoto, spinach, motoho. | Setoto, 4 | *b, c, d, e, f,* babe. |
| | 7.30 p.m. | Wheat bread, motoho. | Wheat, ? | *a, b, c, d, e, f, g.* |

Summary: Wheat, 51 lbs. for 5½ days.
Maize, 37½ lbs. for 5½ days.

| | | | | |
|---|---|---|---|---|
| Oct. 25 | 8.30 a.m. | Wheat bread, sugar, motoho. | Wheat, 12 | *a, b, c, d, e, f, g, h.* |
| | 2 p.m. | Wheat bread, wild carrots. | .. | *b, c, d, e, f.* |
| | 7 p.m. | Wheat bread, spinach. | Wheat, 8 | *a, b, c, d, e, f, g, h.* |

* Setoto from preparation for beer for sale. Weight of maize used 19 lbs. Amount consumed as *setoto* approximately as shown above.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Oct. 26 | 9 a.m. | Wheat bread, motoho, eggs. | .. | *a, b, c.* |
| | | Wheat bread, beef. | Beef, 15 | *d, e, f, g, h.* |
| | 2 p.m. | Wheat bread. | .. | *e, g.* |
| | 4 p.m. | Meat. | .. | *d, e, g, h,* and friend. |
| | 7.30 p.m. | Bread (*a*), meat. | Meal, 6 | *a, d, e, f, g, h.* |
| 27 | 9 a.m. | Bread (*a*), meat. | Meal, 8<br>Meat, 2 | *d, e, f, g, h.* |
| | 1 p.m. | Peas. | Peas, 6½ | *d.* |
| | 3 p.m. | Peas. | .. | *d, e, f, g.* |
| | 5 p.m. | Peas. | .. | *a, h.* |
| | 7 p.m. | Wheat bread, sugar. | Wheat, 7 | *a, d, e, f.* |
| 28 | 8.30 a.m. | Wheat bread, meat. | Wheat, 8<br>Meat, 15 | *a, b, c, d, e, f, g.* |
| | 10 a.m. | Lesheleshele. | Meal, 2½ | *b, c, e.* |
| | 3 p.m. | Wheat bread, meat. | .. | *c, d, e, g.* |
| | 7 p.m. | Wheat bread, meat, motoho. | Meal, 2½ | *a, b, c, d, e, f, g.* |
| | | Eggs. | .. | *a, b.* |
| 29 | 8.30 a.m. | Wheat bread, meat, motoho. | Wheat, 13<br>Meal, 5 | *a, b, c, d, e, f, g.* |
| | 1 p.m. | Wheat bread, motoho. | .. | *b, c, f.* |
| | 7.30 p.m. | Wheat bread, motoho, meat. | Wheat, 7½ | *a, b, c, d, e, f, g,* and guest. |
| 30 | 9 a.m. | Wheat bread, motoho, lesheleshele. | Wheat, 6 | *a, b, c, d, e, f, g,* and 4 guests. |
| | noon | Wheat bread, motoho. | .. | *b, c, f.* |
| | 1.30 p.m. | Motoho. | .. | *c.* |
| | 2.30 p.m. | Wheat bread, motoho. | .. | *d, e, f, g.* |
| | 7 p.m. | Wheat bread, beef, gravy. | .. | *a, b, c, d, e, f, g.* |
| 31 | 8.30 a.m. | Motoho. | Meal, 4½ | *a, b, c, d, e, f, g, h,* and guest. |
| | noon | Motoho. | .. | *b, c, d, e.* |
| | 2 p.m. | Bread (*a*). | Meal, 7½ | *b, c, d, e, f, g.* |
| | p.m. | Bread (*a*), motoho, tea. | .. | *a, b, c, d, e, f, g.* |

Summary of Quantities:

| | | |
|---|---|---|
| Wheat . . . . . . | 61½ lbs. | |
| Maize . . . . . . | 36 lbs. | (excluding unmeasured meal for several dishes). |
| Peas . . . . . . | 6½ lbs. | |
| Meat . . . . . . | 32 lbs. | (probably more). |

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| Nov. 22 | a.m. | Wheat bread, mofehlo, bohoko. | Wheat, 5½ | *a, b, c, d, e, f, g.* |
| | noon | Wheat bread, bohoko. | .. | *a, b.* |
| | p.m. | Wheat bread, milk. | Wheat, 6½ | *a, b, c, d, e, f, g.* |
| 23 | 8 a.m. | Wheat bread, milk. | Wheat, 6 | *a, b, c, d, e, f, g.* |
| | 1 p.m. | Wheat bread, milk. | .. | *c ; f, b* at fields. |
| | 8 p.m. | Wheat bread, milk, tea, spinach. | .. | *a, b, c, d, e, f, g.* |
| 24 | 8.30 a.m. | Wheat bread, motoho. | Wheat, 5<br>Meal, 6 | *a, b, c, d, e, f, g, h.* |
| | 10 a.m. | Lehala. | Meal, 4½ | *b, c, e.* |
| | 2.30 p.m. | Lehala. | .. | *d, f, g.* |
| | 7 p.m. | Wheat bread, milk, meat. | Wheat, 7<br>Meal, 6½ | *a, b, c, d, e, f, g.* |

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Nov. 25 | 9 a.m. | Wheat bread, milk, motoho. | Wheat, 9<br>Meal, 6½ | *a, b, c, d, e, f, g, h.* |
| | 3 p.m. | Wheat bread, milk. | Wheat, 4 | *b, c, e.* |
| | 7 p.m. | Wheat bread, milk. | .. | *a, b, c, d, e, f, g.* |
| 26 | 9 a.m. | Wheat bread, milk. | Wheat, 8 | *a, b, c, d, e, f, g.* |
| | 11.30 a.m. | Wheat bread, milk. | .. | *c.* |
| | 3 p.m. | Wheat bread, milk. | .. | *d, e, f, g.* |
| | 7.30 p.m. | Wheat bread, milk, spinach. | Wheat, 9 | *a, b, c, d, e, f, g.* |
| 27 | 8 a.m. | Wheat bread, milk. | Wheat, 6½ | *a, b, c, d, e, f, g.* |
| | | Beer. | Meal, 10½ | For sale. |
| | 11 a.m. | Beer. | .. | Friends. |
| | 12.30 p.m. | Wheat bread, milk. | .. | *c.* |
| | 7.30 p.m. | Wheat bread, milk. | Wheat, 8 | *a, b, c, d, e, f, g, h.* |
| 28 | 8.30 a.m. | Wheat bread, milk. | Wheat, 7½ | *a, b, c, d.* |
| | 11 a.m. | Wheat bread, milk. | .. | *c.* |
| | 3 p.m. | Wheat bread, milk. | .. | *c, d, e, f.* |
| | p.m. | Wheat bread, spinach. | Wheat, 6 | *a, b, c, d, e, f, g,* and guest. |

Summary of quantities:

Wheat . . . 88 lbs.

Meal . . . 17 lbs. consumed by family—10½ lbs. for beer for sale. Of this a couple of lbs. of *mosoko* must have been eaten.

Meat . . . 6½ lbs. at least.

## *Family No.* 3.

| | | | | |
|---|---|---|---|---|
| Jan. 25 | 8 a.m. | Bread (*a*), milk. | Meal, 8 | Family and 1 guest. |
| | noon | Bread (*a*), milk. | .. | Children and guests (2). |
| | 2.30 p.m. | Bread (*a*), milk. | .. | Children. |
| | 8 p.m. | Wheat bread. | Wheat, 9 | Family and guest. |
| 26 | 8 a.m. | Wheat bread. | Wheat, 16 | Family and guest. |
| | noon | Wheat bread, milk. | .. | Children and guests (2). |
| | 8 p.m. | Wheat bread. | .. | Family and guest. |
| 27 | 8 a.m. | Bread (*a*), milk. | Meal, 10 | Family and guest. |
| | noon | Bread (*a*), milk. | .. | Children and guest. |
| | 8 p.m. | Bread (*a*), milk. | .. | Family. |
| 28 | 8 a.m. | Bread (*a*), mofehlo. | Meal, 9½ | Family. |
| | noon | Bread (*a*), mofehlo. | .. | Children and guest. Women at fields. |
| | 8 p.m. | Bread (*a*), mofehlo. | .. | Family. |
| 29 | 8 a.m. | Wheat bread. | Wheat, 15 | Family. |
| | noon | Wheat bread, mofehlo. | .. | Family, less head. |
| | 8 p.m. | Wheat bread. | .. | Family. |
| 30 | 8 a.m. | Wheat bread. | .. | Family. |
| | noon | Bread (*a*), mahleu. | Meal, 12 | Family. |
| | 8 p.m. | Bread (*a*), mofehlo, mahleu. | .. | Family and guest. |
| 31 | 8 a.m. | Bread (*a*), milk. | Meal, 12 | Family and guest. |
| | noon | Bread (*a*), milk, mahleu. | Meal, 3 | Family. |
| | 8 p.m. | Bread (*a*), milk. | .. | Family. |

Summary of quantities:

Wheat . . . . . 40 lbs.

Meal (bread, mahleu) . . 54 lbs.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Feb. 15 | ? | Bread (*a*), milk, or mofehlo and mahleu. | Meal, 11½<br>Meal, 4 | Family. |
| 16 | a.m. | Bread (*a*), milk, mahleu. | .. | Family. |
| | p.m. | Wheat bread, green mealies. | Wheat, 13<br>Maize, 12 | Family. |
| 17 | a.m. | Wheat bread, green mealies. | .. | Family. |
| | p.m. | Wheat bread, green mealies. | .. | Family. |
| 18 | a.m. ? | Bread (*a*), mofehlo. | Meal, 9 | Family. |
| | p.m. | Bread (*a*), mofehlo. | .. | Family. |
| 19 | a.m. | Wheat bread. | Wheat, 13½ | Family. |
| | p.m. | Wheat bread. | .. | Family. |
| 20 | a.m. | Wheat bread, milk. | .. | Family. |
| | p.m. | Bread (*a*), mofehlo. | Meal, 15½ | Family. |
| 21 | a.m. | Bread (*a*), mofehlo. | .. | Family. |
| | p.m. | Bread (*a*), milk. | Meal, 5 | Family. |

Summary of quantities:

Wheat . . . . . 26½ lbs.
Meal . . . . . 45 lbs.
Maize . . . . . 12 lbs.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| Mar. 22 | 8 a.m. | Bread (*a*). | Meal, 9 | Family. |
| | noon | Bread, milk. | .. | Women and children. |
| | p.m. | Bread (*a*), lentils. | .. | Family. |
| 23 | a.m. | Bread (*a*). | .. | Family. |
| | noon | Bread (*a*), potatoes, pumpkin, milk. | .. | Women and children. |
| | p.m. | Bread (*a*), pumpkin, mofehlo. | .. | Family. |
| 24 | a.m. | Bread (*a*), pumpkin, green mealies and milk. | Meal, 8 | Family. |
| | noon | Bread (*a*), pumpkin. | .. | Children. |
| | 2 p.m. | Bread (*a*), coffee. | .. | Women and children. |
| | p.m. | Bread (*a*). | .. | Family. |
| 25 | a.m. | Bread (*a*), milk. | .. | Family. |
| | noon | Bread (*a*), tea. | .. | Women and children. |
| | p.m. | Wheat bread, milk. | Wheat, 7 | Family. |
| 26 | a.m. | Wheat bread. | .. | Family. |
| | noon | Wheat bread, pumpkin, green mealies. | .. | Children. |
| | p.m. | Wheat bread, pumpkin. | .. | Family. |
| 27 | a.m. | Bread (*a*), mofehlo. | Meal, 8 | Family. |
| | noon | Bread (*a*), tea. | .. | Women and children. |
| | p.m. | Bread (*a*), coffee. | .. | Family. |
| 28 | a.m. | Bread (*a*), mofehlo, mahleu. | Meal, 3 | Family. |
| | noon | Bread (*a*). | .. | Children. |
| | p.m. | Bread (*a*), pumpkin, mahleu. | .. | Family. |

Summary of quantities:

Meal for bread and mahleu . . . . 28 lbs.
Wheat . . . . . . . . . . 7 lbs.

This family was running a little short of grain, but was able to manage fairly comfortably by making up for this on pumpkin.

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*Note.*—In this and the following months the family probably consisted of four adults and the two children, with occasional comings and goings of adults and visitors. Unfortunately these have not been noted in the records.

| Date. | Time. | Food. | Weight. | Consumers. |
| --- | --- | --- | --- | --- |
| | | | lbs. | |
| Apr. 23 | ? | Bread (*a*), beer. | Meal, 10 | Family. |
| 24 | .. | Bread (*a*), mahleu, moroko. | Meal, 2½ | Family. |
| 25 | .. | Bread (*a*), mahleu. | | |
| 26 | .. | Wheat bread. | Wheat, 7 | |
| 27 | .. | Wheat bread. | | |
| 28 | .. | Bread (*a*). | Meal, 10 | |
| 29 | .. | Bread (*a*). | | |
| | Summary: | | | |
| | | Meal . . . . . . | 22½ lbs. | |
| | | Wheat . . . . . . | 7 lbs. | |

Only the weights of the foods have been recorded. The daily consumption of foods was probably very similar to that shown for the last month—a fair amount of milk in one form or another, with a lot of pumpkin and occasional green mealies. The effect of the harvest in replenishing their grain stores would not be fully felt until May and June.

*Family No. 4.*

| Date. | Time. | Food. | Consumers. |
| --- | --- | --- | --- |
| Dec. 25 | a.m. | Bread (*a*), mahleu. | Family. |
| | p.m. | Bread (*a*), boiled maize. | |
| 26 | a.m. | Bread (*a*), mahleu. | |
| | p.m. | Bread (*a*), motoho. | |
| 27 | noon | Bread (*a*), mahleu. | |
| | p.m. | Bread (*a*), mahleu. | |
| 28 | a.m. | Bread (*a*), mahleu. | Younger son. |
| | noon | Bread (*a*), mahleu, boiled peas and mealies. | Family. |
| | p.m. | Neck of sheep (given to boys at Chief's). | Boys. |
| 29 | noon | Bread (*a*), mofehlo and whey (given at Chief's). | Family. |
| | p.m. | Bread (*b*), mofehlo, mahleu. | Family. |
| 30 | noon | Bread (*b*), mofehlo, mahleu. | Family. |
| | 2 p.m. | Mahleu. | Boys. |
| | 7 p.m. | Bread (*b*), mofehlo. | Younger son. |
| | 9 p.m. | Bread (*b*), mofehlo, boiled maize. | Mother and elder son. |
| 31 | 9.30 a.m. | Motoho. | Boys (mother took food to fields). |
| | 1 p.m. | Bread (*a*), Spinach. | Boys. |
| | 7 p.m. | Motoho. | Younger son. |
| | 8.30 p.m. | Bread (*a*), mofehlo. | Mother and elder son. |

*Note.*—The elder boy used to gather and eat a few wild plants, such as berries, roots, etc., in the veld when he was herding. He also sucked cows after milking, and occasionally let his young brother do the same.

Their mother at this time was weeding in the fields and occasionally working at the Chief's.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Jan. 25 | a.m. | Lesheleshele. | Meal, 4 | Mother and younger son. |
| | 1.30 p.m. | Bread (*a*), mofehlo. | .. | Family. |
| | 6.30 p.m. | Meat. | .. | elder son at khotla. |
| | 8 p.m. | Bread (*a*), mofehlo. | .. | Family. |
| 26 | a.m. | Bread (*a*), mofehlo. | .. | Younger son. |
| | noon | Bread (*a*), gravy. | .. | Mother and younger son. |
| | 2.30 p.m. | Bread (*a*), mofehlo. | .. | Mother and elder son. |
| | 8 p.m. | Bread (*b*), mofehlo. | Meal, 6 | Family. |
| 27 | 9 a.m. | Bread (*b*), mofehlo. | .. | Boys. |
| | noon | Bread (*b*), mofehlo. | .. | Family. |
| | 2 p.m. | Mosoko, mofehlo. | .. | Family. |
| | 8.30 p.m. | Bread (*b*), mofehlo. | Meal, 8 | Family and guest. |
| 28 | 8 a.m. | Bread (*b*), mofehlo. | .. | Family. |
| | noon | Bread (*b*), mofehlo. | .. | Family and guest. |
| | 2 p.m. | Bread (*b*), mofehlo. | .. | Family (mother working in fields). |
| | 8.30 p.m. | Mosoko and lesheleshele | .. | Family (younger son ate earlier) and guest. |
| 29 | 8 a.m. | Bread (*b*), whey. | .. | Family. |
| | 3 p.m. | Bread (*b*), mofehlo. | Meal, 5 | Family (mother working in fields). |
| | 8.30 p.m. | Bread (*a*), mofehlo, spinach. | .. | Family and guest. |
| 30 | 8 a.m. | Bread (*a*), mofehlo. | .. | Family. |
| | 3 p.m. | Bread (*a*), mofehlo. | .. | Family. |
| | 8.30 p.m. | Bread (*a*), mofehlo, green peas, spinach. | .. | Family and guest. |
| 31 | noon | Bread (*a*), mofehlo, spinach. | Meal, 4 | Boys. Mother ate at Chief's. |
| | 8.30 p.m. | Bread (*a*), mofehlo. | .. | Family and guest. |

Summary of quantities: maize, 27 lbs. for 7 days.

*Note.*—For the midday meals the mother is shown as being present with her sons. This is done for convenience: most days she was working in the lands, but since she took the same food with her as her sons had, her absence from the village at this meal has no effect on the actual food intake of each individual.

The regularising effect of school, which opened on January 27, on the times of morning and midday meals is noticeable. January 31 was a holiday.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Feb. 23 | 8 a.m. | Bread (*a*), mofehlo. | Meal, 8 | Family and 2 guests (1 adult, 1 boy). |
| | noon | Motoho. | .. | Family and 2 guests (1 adult, 1 boy). |
| | 2 p.m. | Bread (*a*), mofehlo. | .. | Boys and 2 friends. |
| | 8 p.m. | Bread (*a*), mofehlo. | .. | Family and 2 boys (friends). |

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Feb. 24 | 8 a.m. | Bread (*a*), mofehlo. | .. | Family and 2 boys (friends). |
| | noon | Boiled maize (brought by neighbour). | .. | Mother. |
| | 7 p.m. | Bread (*a*), mofehlo. | .. | Family and guest (12 years). |
| 25 | 8 a.m. | Green peas, pumpkin. | Meal, 10 | Family. |
| | 2.30 p.m. | Bread (*a*), mofehlo. | .. | Family and 2 guests (12 years). |
| | 8 p.m. | Bread (*a*), mofehlo. | .. | Family and guest (12 years). |
| 26 | 8 a.m. | Bread (*a*), mofehlo. | .. | Family and guest (12 years). |
| | noon | Mosoko. | .. | Mother at Chief's. |
| | 2.30 p.m. | Bread (*a*), mofehlo. | .. | Boys and guest (12 years). |
| | 8 p.m. | Bread (*a*), mofehlo. | Meal, 5 | Family and guest (12 years). |
| 27 | 8 a.m. | Bread (*a*), mofehlo. | .. | Family and guest (12 years). |
| | noon | Bread (*a*), mofehlo. | .. | Family and 2 guests (1 adult, one 12 years). |
| | 2.15 p.m. | Bread (*a*), mofehlo. | .. | Boys and guest (12 years). |
| | 8 p.m. | Bread (*a*), mofehlo, green peas and mealies. | Meal, 8 | Family and guest (12 years). |
| 28 | 8 a.m. | Bread (*a*), mofehlo. | .. | Family and guest (12 years). |
| | 2 p.m. | Green peas. | .. | Family and 2 guests (as above). |
| | 8 p.m. | Bread (*a*), green peas. | Meal, 6 | Family and guest (12 years). |
| 29 | 8 a.m. | Bread (*a*), mofehlo. | .. | Family and guest (12 years). |
| | noon | Bread (*a*), mofehlo. | .. | Family and guest (12 years). |
| | 2.30 p.m. | Bread (*a*), mofehlo. | .. | Boys and guest (as above). |
| | 8 p.m. | Bread (*a*), mofehlo. | .. | Family and guest (as above). |

Summary of quantities:
mealie meal, 37 lbs. for the week.
Peas, ?

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| Mar. 25 | a.m. | Bread (*a*), whey. | Meal, 6 | Boys and friend. |
| | | Motoho. | .. | Mother. |
| | noon | Bread (*a*), motoho, mofehlo. | .. | Family and guest. |
| | p.m. | Bread (*a*), mofehlo. | .. | Family and guest. |
| 26 | a.m. | Bread (*a*), mofehlo. | Meal, 4 | Family. |
| | noon | Bread (*a*), mofehlo. | .. | Family. |
| | p.m. | Bread (*a*), mofehlo. | .. | Family. |
| 27 | a.m. | Bread (*a*), mofehlo. | Meal, 5 | Family and guest. |
| | noon | Bread (*a*), mofehlo. | .. | Family and guest. |
| | p.m. | Bread (*a*), mofehlo, bohoko. | .. | Family and guest. |

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Mar. 28 | a.m. | Bread (*a*), mofehlo. | Meal, 9 | Family and guest. |
| | noon | Bread (*a*), mofehlo. | .. | Family and guest. |
| | | Lehala. | .. | Mother at Chief's. |
| | | Pumpkins. | .. | Elder son at friends. |
| | p.m. | Bread (*a*), mofehlo, green mealies. | .. | Family and 2 guests. |
| 29 | a.m. | Bread (*a*), mofehlo, mahleu. | .. | Family and guest. |
| | noon | Bread (*a*), mofehlo. | .. | Family. |
| | p.m. | Bread (*a*), mofehlo. | .. | Family and guest. |
| | | Bohoko. | .. | Elder son at Chief's. |
| 30 | a.m. | Bread (*a*), mofehlo. | Meal, 10 | Family and guest. |
| | noon | Bread (*a*), mofehlo. | .. | Family and guest. |
| | | Green mealies. | .. | Mother and guest. |
| | | Lesheleshele. | .. | Sons. |
| | p.m. | Bread (*a*), mofehlo, green mealies. | .. | Family and guest. |
| 31 | a.m. | Bread (*a*), mofehlo. | .. | Family and guest. |
| | noon | Bread (*a*), mofehlo. | .. | Family and guest. |
| | p.m. | Bread (*a*), mofehlo. | .. | Family. |

Summary of quantities: Maize, 34 lbs. for week. Add 2 lbs. for *lesheleshele* and *motoho*. Green mealies?

*Note.*—The permanent guest was the woman's lover.

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Apr. 24 | ? | Wheat bread, mofehlo. | Wheat, 5 | Family. |
| 25 | .. | Wheat bread, mofehlo. | Wheat, 10 | Family. |
| 26 | .. | Wheat bread, mofehlo. | .. | Family. |
| 27 | .. | Wheat bread, mofehlo. | .. | Family. |
| 28 | .. | Bread (*a*), mofehlo. | Meal, 5 | Family. |
| 29 | .. | Bread (*a*), mofehlo. | .. | Family. |
| 30 | .. | Bread (*a*), mofehlo. | Meal, 2 | Family. |

Summary of quantities:

Maize for bread . . . 7 lbs.
Wheat for bread . . . 15 lbs.

*Note.*—Only the above details were recorded. It is probable that in addition to the above, a few peas were eaten.

*Family No. 5.*

| Date. | Time. | Food. | Consumers. | Work. |
|---|---|---|---|---|
| Dec. 25 | 10 a.m. | Bread (*a*), mahleu, roast maize. | Family. | Wife and sister grind, 7–8.30 a.m. |
| | 2 p.m. | Bread (*a*), spinach. | Family. | Wife gathers spinach, 1 hour. |
| | 8 p.m. | Bread (*a*), mahleu. | Family. | Wife and sister grind, 50 minutes. |
| 26 | 8 a.m. | Bread (*a*), mahleu. | Family. | Sister weeds fields, 11 hours. Wife grinds, 1½ hours. |
| | 4 p.m. | Mahleu. | Head. | Inspects fields, 12–4 p.m. |
| | 9.30 p.m. | Bread (*a*), mahleu, spinach, roast maize. | Family. | |
| 27 | 9 a.m. | Bread (*a*), mahleu, roast maize. | Family. | Wife mends seotloana, 10 a.m.–6 p.m. |
| | 8 p.m. | Bread (*a*), motoho, meat. | Family and friend visiting. | Husband kills sheep and stretches skin. |
| 28 | 9.30 a.m. | Bread (*a*), motoho, meat and gravy. | Family and friend visiting. | Wife grinds, 6–7 a.m. |
| | 9 p.m. | Bread (*a*), meat. | Family and friend visiting. | |
| 29 | 9.30 a.m. | Bread (*a*), lesheleshele. | Family and friend visiting. | |
| | 8 p.m. | Bread (*a*), meat, lesheleshele. | Family and friend visiting. | |
| 30 | 8 a.m. | Bread (*a*), mahleu, spinach. | Family and friend visiting. | Wife grinds grain then finishes seotloana, 7 a.m.–2 p.m. |
| | noon | Bread (*a*), spinach. | Family and friend visiting. | |
| | 8 p.m. | Bread (*a*), meat, mahleu. | Family and friend visiting. | |
| 31 | 8 a.m. | Bread (*a*), gravy, mahleu. | Family and friend visiting. | Washing day, 8 a.m.–2 p.m. |
| | 8.30 p.m. | Bread (*a*), motoho. | Family. | |

| Date. | Time. | Food. | Weight. | Consumers. | Work. |
|---|---|---|---|---|---|
| Jan. 25 | 8 a.m. | Bread (*a*), tea. | .. lbs. | Family. | |
| | noon | Bread (*a*), tea. | .. | Family. | |
| | 9 p.m. | Bread (*a*), mess of peas. | Peas, 5 | Family. | |
| 26 | 10 a.m. | Bread (*b*), mess of peas. | Maize, 17 | Family. | Wife sewed, 10 a.m.–1 p.m. |
| | 8 p.m. | Bread (*b*), mess of peas. | Peas, 8 | Family. | |
| 27 | 9 a.m. | Bread (*b*), green peas and motoho. | .. | Family. | |
| | 8 p.m. | Wheat bread, spinach. | Wheat, 12 | Family. | |
| 28 | 10 a.m. | Wheat bread, motoho. | Maize, 9 | Family. | |
| | 1 p.m. | Wheat bread. | .. | Wife and children. | |
| | 8 p.m. | Wheat bread, boiled maize. | Maize, ? | Family. | |
| 29 | 8 a.m. | Wheat bread, boiled maize, motoho. | Maize, ? | Family. | Wife weeded, 9½ hours. |
| | 1 p.m. | Wheat bread, boiled maize, motoho. | .. | Children. | |
| | 8.30 p.m. | Bread (*a*) spinach. | Maize, 3 | Family. | |
| 30 | 8 a.m. | Bread (*a*), motoho. | .. | Family. | Wife weeds for 8 hours. |
| | 2 p.m. | Bread (*a*), motoho. | .. | Children. | |
| | 8.30 p.m. | Bread (*a*), chicken. | Maize, 4½ | Family. | |
| 31 | 8 a.m. | Bread (*a*), chicken. | .. | Family. | Wife weeds for 9 hours. |
| | 2 p.m. | Bread (*a*). | .. | Children. | |
| | 8.30 p.m. | Bread (*a*), gravy. | .. | Family. | |

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Feb. 23 | 8 a.m. | Wheat bread, green maize. | .. | Family and guest. |
| | noon | Wheat bread, motoho. | .. | Family and guest. |
| | 8 p.m. | Wheat bread, cabbage. | .. | Family and guest. |
| 24 | 8.30 a.m. | Wheat bread, cabbage, mahleu. | Wheat, 5 | Family and guest. |
| | noon | Wheat bread, spinach, mahleu. | .. | Family and guest. Wife away. |
| | 2 p.m. | Wheat bread, mahleu. | .. | Family and guest. Wife away. |
| | 8 p.m. | Wheat bread, mahleu. | Wheat, 10 | Family and guest. |
| 25 | 8 a.m. | Wheat bread, mahleu. | .. | Family and guest. |
| | 2 p.m. | Mahleu. | .. | Head. |
| | 3.30 p.m. | Mahleu. | .. | Head and 4 friends. |
| | 8.30 p.m. | Wheat bread, spinach. | Wheat, 1½ | Family. |
| 26 | 8.30 a.m. | Maize bread (*a*), spinach. | Maize, 8½ | Family. |
| | noon | Bread (*a*), spinach. | .. | Wife and children. |
| | 9 p.m. | Bread (*a*), boiled maize. | Maize, 8 | Family. |
| 27 | 8.30 a.m. | Bread (*a*), boiled maize. | .. | Family. |
| | noon | Bread (*a*), lesheleshele. | Maize, 5 | Children, younger. |
| | 2 p.m. | Bread (*a*). | .. | Father and older children. |
| | 8.30 p.m. | Bread (*a*), chicken. | Maize, 4 | Family. |
| 28 | 8.30 a.m. | Bread (*a*). | .. | Family minus wife (sick). |
| | .. | Lesheleshele. | Maize, 2 | Wife. |
| | 3 p.m. | Bread (*a*). Eggs (for Head). | .. | Family minus wife. |
| | 9 p.m. | Bread (*a*), chicken. | Maize, 8 | Family. |
| 29 | 9 a.m. | Bread (*a*), mahleu. | Maize, 4 | Family and guest. |
| | 3 p.m. | Bread (*a*), mahleu. | Maize, 5½ | Family. |
| | 8.30 p.m. | Bread (*a*). | .. | Family. |
| Mar. 25 | 9 a.m. | Bread (*a*), potatoes, hlenhlenyane. | Meal, 4 | Family and guest. |
| | noon | Bread (*a*), green mealies. | .. | Children (2 years). |
| | 2 p.m. | Bread (*a*), pumpkin. | .. | Family. |
| | 8 p.m. | Bread (*a*). | .. | Family. |
| 26 | 9 a.m. | Wheat bread. | Wheat, 10 | Family. |
| | noon | Wheat bread. | .. | Children (2 years). |
| | 2 p.m. | Wheat bread. | .. | Family. |
| | 8 p.m. | Wheat bread, leting. | Wheat, 10 | Family and guest. |
| 27 | 8 a.m. | Wheat bread, leting. | Wheat, 8 | Family and guest. |
| | noon | Wheat bread, leting. | .. | Family. |
| | 2 p.m. | Wheat bread. | .. | Family. |
| | 8 p.m. | Green mealies, hlenhlenyane. | Wheat for hlenhl. 3 | Family. |
| 28 | 9 a.m. | Wheat bread, hlenhlenyane. | Wheat, 8 | Family. |
| | noon | Wheat bread, boiled peas. | .. | Family and guest. |
| | 8 p.m. | Wheat bread, eggs. | .. | Family. |
| 29 | 8 a.m. | Wheat bread, spinach. | Wheat, 9 | Family. |
| | noon | Wheat bread, spinach. | .. | Family. |
| | 8 p.m. | Wheat bread, spinach. | .. | Family. |
| 30 | 9 a.m. | Wheat bread, spinach, hlenhlenyane. | Wheat for hlenhl. 3 | Family. |
| | noon | Wheat bread, boiled peas. | .. | Family. Wife away. |
| | 2 p.m. | Boiled peas. | .. | Family. |
| | 8 p.m. | Green mealies, pumpkin, hlenhlenyane. | .. | Family and 4 guests. |

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Mar. 31 | 9 a.m. | Green mealies, pumpkin. | .. | Family and 4 guests. |
| | noon | Wheat bread. | Wheat, 8 | Family. |
| | 2 p.m. | Wheat bread. | .. | Family. |
| | 7 p.m. | Wheat bread, green mealies. | .. | Family. |

Summary of weights: Mealie meal, 4 lbs. Wheat for bread, 55 lbs. Wheat for *hlenhlenyane*, 6 lbs. Peas? Green mealies? (probably not more than one or two cobs each person).

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Apr. 24 | 9 a.m. | Wheat bread, motoho (given by neighbours). | Wheat, 9 | Family. |
| | 2.30 p.m. | Wheat bread. | .. | Family. |
| | 8 p.m. | Wheat bread, mahleu. | .. | Family and guest. |
| 25 | 8 a.m. | Wheat bread. | Wheat, 7½ | Family and guest. |
| | 1 p.m. | Wheat bread, meat. | .. | Family and 2 guests. |
| | 8 p.m. | Wheat bread, meat. | Wheat, 8 | Family and 2 guests. |
| 26 | 9 a.m. | Wheat bread, meat. | .. | Family and 2 guests. |
| | noon | Wheat bread, meat. | Wheat, 4½ | Family and 2 guests. |
| | 9 p.m. | Wheat bread, meat. | .. | Family and 2 guests. |
| 27 | 9 a.m. | Wheat bread, meat. | Wheat, 10 | Family and 2 guests. |
| | noon | Wheat bread, meat. | .. | Family, minus Head away on census. |
| | 8 p.m. | Wheat bread, meat. | .. | Head do. |
| 28 | 8.30 a.m. | Wheat bread, meat. | Wheat, 9 | Head do. |
| | noon | Wheat bread, meat. | .. | Head do. |
| | 9 p.m. | Wheat bread, meat. | .. | Head do. |
| 29 | 8.30 a.m. | Wheat bread, gravy. | Wheat, 13 | Head do. |
| | noon | Wheat bread, gravy. | .. | Head do. |
| | 7 p.m. | Wheat bread. | .. | Head do. |
| 30 | 9 a.m. | Wheat bread, meat. | .. | Head do. |
| | noon | Wheat bread, gravy. | .. | Head do. |
| | 7 p.m. | Wheat bread. | .. | Head do. |

Summary of food quantities:

| | |
|---|---|
| Wheat . . . . . . | 61 lbs. |
| Meat . . . . . . | 1 sheep. |

Pumpkin, though not shown, must have been eaten occasionally, as this is the season for them, and this family was keener on vegetables than most.

*Family No. 6.*

| Date. | Time. | Food. | Weight. | Consumers. |
|---|---|---|---|---|
| | | | lbs. | |
| Jan. 25 | .. | Bread (*a*), mahleu, motoho and spinach. | Meal/bread, 8<br>Meal/mahleu, 9½ and motoho. | Family and 2 guests. |
| 26 | .. | Bread (*a*), mahleu, motoho and spinach. | .. | Family and 1 guest. |
| 27 | .. | Bread (*a*). | Meal/bread, 5 | Family and 1 guest. |
| 28 | .. | Bread (*a*), mahleu. | Meal/bread 9 and mahleu, | Family and 1 guest. |
| 29 | .. | Bread (*a*), mahleu. | .. | Family and 1 guest. |
| 30 | .. | Bread (*a*), mahleu. | Meal/bread, 6½<br>Meal/mahleu, 3 | Family and 1 guest. |
| 31 | .. | Bread (*a*), mahleu. (Beer being brewed for sale, meal/beer 15 lbs.) | .. | Family. |
| Feb. 14 | .. | Bread (*a*). | Meal/bread, 6½ | Family. |
| 15 | .. | Bread (*a*). | Meal/bread, 3 | Family. |
| 16 | .. | Bread (*a*), spinach ?. | .. | Family. |
| 17 | .. | Bread (*a*). | Meal/bread, 5 | Family. |
| 18 | .. | Bread (*a*), green mealies (from parents). | .. | Family. |
| 19 | .. | Bread (*a*), spinach ?. | Meal/bread, 8 | Family. |
| 20 | .. | Bread (*a*), green mealies (from wife's parents). | .. | Family. |
| Mar. | .. | Supplies failed. Family lived on charity of neighbours. | | |

Summary of weights: Total weight of maize prepared by family for consumption during week of January, 41 lbs.; February, 22½ lbs., excluding green maize, March ?.

*Note.*—The reason for taking the third week in February instead of the last is that the mother left on the 21st to visit her maternal uncle, leaving her family with her mother-in-law, and although she returned on the 25th, she was too ill to prepare them any food.

## APPENDIX IV.

### Sotho Cookery.

The BaSotho have a large collection of recipes, and starting from a single raw material, maize, wheat or kaffir corn, can produce a surprising variety of dishes. Owing, however, to the time taken in their preparation and the many other calls on the women's labour (for except when travelling or at the cattle posts, men never cook, though some say they are more skilful than women), the women take as little trouble as possible over their cooking and seldom venture from a narrow round of simple conventional dishes. It is only in the wealthier homes where there are servants or other dependents, such as the daughters of poor relations, to help with the housekeeping that any variety of dishes is, in practice, to be found

Even here, however, Suto cookery does not aspire to the dignity of gastronomic art; it knows nothing of sauces or of the finer points of flavour, and although there are subtle degrees of good and bad cooking, it does not aim further than the production of "plain, wholesome food" (though sometimes it scarcely achieves even that). It claims little more than simple variety, and for this, at least, credit must be given in that it saves the diet from extreme monotony.

Below are given the recipes of some of the more common dishes, and the list is by no means exhaustive. The frequency with which they are used can be seen from the diet records quoted in Appendix III.

## Maize.

The whole grain is cooked either by boiling until soft (often with peas), by roasting on the cob, or by frying, and then being ground and mixed with sugar or salt. The latter is mainly used as a food for journeys (though it is also occasionally used at home) for the reason that it is light to carry, and that when washed down by a drink of water, it swells in the stomach and creates a pleasant feeling of satisfaction!

Most maize is cooked as a meal and is used for both liquid and solid foods. It is ground—as all other kinds of grain—between two stones, or where this instrument can be afforded, by small hand mills. The fineness of the meal depends largely on the skill of the worker, but it is usually surprisingly fine and light. Except in the case of wheat used for bread and maize being prepared for motoho, the flour or meal is never sifted but is always used whole. In this respect the BaSotho are considerably better off than those tribes (*e.g.* in Bechuanaland) who have to pound their grain and sift it to remove the coarser particles. As indicated below, in the preparation of certain dishes, the grain is first coarsely ground (*haila*), partially cooked, and then ground again as a wet mush (*nepola*).

*Solid Foods.*—The solid foods for which maize meal is used are principally breads (*bohobe*) of one sort or another. The commonest of these is pap (*papa, phaté* or *bohobe ba lephokojoa*). It is easy to prepare and economical in use.

Finely ground mealie meal is poured into boiling water, stirred and cooked for a few minutes, and stirred again. Sometimes the meal is added in small quantities at a time, as when the cook who has not had time to grind enough by the time the water started boiling, empties into the pot the amounts collected on the little mat in front of her grindstone. The whole (which forms a floating pyramid of meal) is not stirred until the last of the meal is added—so that though the bottom of the pyramid has been in contact with the boiling water for a quarter to half an hour, the rest of the meal has not been much affected though literally being in the pot. When cooked the pap is served as dry, somewhat sticky, bread and may be eaten hot. Any surplus—and usually enough is cooked to last several meals—is rolled into large balls (about 5–6 inches in diameter) called *polokoe*, in which form it keeps fresh for several days. The time taken for cooking (from the first stirring to the last) varies from 5 minutes to about 20 minutes, depending on the impatience of a hungry family or the conscientiousness of the cook, and is usually too short. According

to Dr. Motebang of Mokhotlong, this badly and insufficiently cooked phate is one of the principal causes of the indigestion and other stomach troubles from which the Basuto frequently suffer.

This phate is not an appetising dish, but it is filling, and a little goes a long way. It is therefore economical, and consequently is usually prepared by the poor, and when grain supplies are running low. To hide its tastelessness people usually eat it with milk or with a relish such as spinach or gravy, and the phrase "*ho ja phate*" (to eat pap by itself) is a contemptuous signification of poverty.

The other bread, *bohobe ba senyahatso* (or *ba menepolo* or *ba linkhoa*), is more appetising, less economical, and takes longer to prepare. So it is only used frequently in wealthier families. Coarsely ground meal is boiled for an hour or so, re-ground, shaped into small loaves and steamed until cooked.

## Liquid Foods.

1. *Lesheleshele.*—Fine mealie meal is added to boiling water (or whey), thoroughly stirred and then boiled slowly for half an hour or so, being stirred occasionally with a whisk. It is not unpleasant, but being regarded as a woman's food, is used mainly by invalids, children and nursing mothers. (Europeans often have *lesheleshele* for breakfast.)

2. *Motoho.*—This is similar to but thicker than the above. It is twice cooked, and is sometimes leavened with native yeast. In its preparation the coarser meal is sifted out and thrown away. The poorer families cannot afford this slight waste, and so, though it is a palatable food, only the better off use it at all frequently, the others having it only for invalids and nursing mothers. Teetotalers sometimes drink it instead of beer, and the unleavened motoho is used mainly for babies.

3. *Mahleu* is a very refreshing non-alcoholic drink made of a mealie meal paste. This is added to boiling water, stirred and cooked; leavened when hot with ground sprouted mabele or wheat, and when cooled, with a little yeast. After it has begun to ferment it is strained and is then ready for use. It is a delightful cooling drink, and is widely used both at home and by workers in the fields.

4. *Leting* is a slightly alcoholic drink (in the hands of the expert it can be made intoxicating) with a slightly bitter taste. It is made of coarse meal cooked and re-ground. To this boiling water is added, and the whole cooked again. When cool it is leavened first with yeast and later with ground sprouted kaffir corn or wheat, allowed to stand a day or so and then strained before use. It is also a popular drink for ordinary use, but is not often given to children. It is usually made with kaffir corn, though maize can also be used.

5. *Kaffir Beer.*—The initial stages in its making are the same as for *leting*. After the ingredients have been cooked, cooled and leavened with yeast, it is allowed to ferment for a day, while the meal sinks leaving a clear liquid on top. This is drained off, boiled and mixed with the meal, and the whole boiled again for three or four hours, turning to a thick porridge-like substance called setoto. This is poured off into large beer pots, and when cool is leavened again with sprouted *mabele* or wheat, and also a little yeast. After standing a day, it is strained and is ready

for use. The solid stuff that is strained away is of two kinds. The coarser, *mosoko*, is thrown away or fed to animals; the finer, *moroko*, is kept and eaten as it is or slightly steamed. The main ingredient of beer in the Lowlands is kaffir corn, in the mountains it is wheat. The latter makes a bitterer drink, which is also slightly more potent.

Beer is the social drink *par excellence* and is used on all ceremonial and festive occasions. As it attracts friends and visitors to the brewer's and is quickly consumed by the crowd of guests, it is only the richer people who can afford to have it often. It then acts as both food and drink, a regular beer drinker eats or drinks little else besides, an indulgence that leads to gastric and other disorders due to induced over-acidity. Poorer people only have beer occasionally, chiefly for some celebration. But many of them (I knew of five out of forty families) brew beer for sale in order to earn a little money to buy essentials such as grain and clothes, and girls also brew beer for sale to make a little "pin" money. (*Note.*—The practice is illegal, but is winked at by the native authorities because it enables people to have a little beer occasionally without having to go to the expense of making a full brew, and because it is one of the very few ways widows and other poor people make a little ready money. In or near the Camps and large villages it is often associated with prostitution and thieving, and forms the main means of livelihood of dissolute and unattached women. But elsewhere in the case of the occasional brewers in the small villages, who form the great majority, it is neither harmful nor vicious.)

Beer is drunk by adults of both sexes, but not by children, with the possible exception of children, in the Camps and larger villages. But even here it is not a common thing. *Setoto*, however, is frequently eaten as a sort of porridge.

## Other Dishes.

1. *Hlenhlenyane.*—This is somewhat similar to Motoho, in its consistency. Fine mealie meal is boiled an hour or so with water, leavened with ground-sprouted wheat (or mabele), diluted and leavened again with yeast. When it ferments, the meal separates out, leaving a clear liquid. This is boiled, mixed again with the meal, and the whole thoroughly stirred. It is then ready for use. It is not a common dish.

2. *Lehala*—Meal is stirred into boiling fresh milk, cooked a few minutes and allowed to cool. The result is a white solid substance, of much the same consistency as a blancmange. It is an appetising dish and is very satisfying, but since it uses up a lot of milk and is quickly eaten, it can only be afforded by the richer people.

## Kaffir Corn.

In the mountains Kaffir corn is never used, except in the sprouted stage, as mela for beer brewing or by the wealthy on important occasions such as an initiation feast. It can be substituted for maize in all the abovementioned recipes, and in the Lowlands is sometimes used for bread, etc., but most of it is used for brewing beer and leting, and for making *motoho*

and *lesheleshele*. It might, however, be noted that it is not as widely used as is generally believed: it stands second to maize, with the latter well in the lead.

### Wheat.

As has been mentioned in the main paper, wheat is a new crop to the BaSotho, and except in the Highlands, where it has forced itself into favour, it is seldom used. But in the Highlands it is a very popular food, and, as the records in Appendix I show, is widely used. Amongst the wealthy families it is frequently and regularly eaten, but the poorer people only have it as a treat to break the monotony of their maize diet and as a luxury at feasts. The reason for this is that being a nicer and lighter food, people eat more of it than maize, because they like it and because they have to eat more of it to give them the same feeling of satisfaction or repletion. Consequently it is less economical; moreover, since it fetches a better price it pays to sell it rather than maize.

Wheat is cooked in a number of ways, but is mostly used for bread. There are two sorts of bread, but the initial preparation of both is the same. The flour is kneaded into a thick dough, leavened and left overnight. Next day it is mixed with a little more flour and the dough divided into small loaves. Then in one case it is baked, an ordinary pot being used with a fire underneath it and live coals heaped on top. In the second case it is steamed. The baked bread is the better flavoured, but both are good and are much nicer than any of the maize breads.

### Legumes.

Peas are either boiled (green or ripe and hard) or are cooked into a sort of pottage or very thick soup. Beans are mainly cooked in the latter way. This pottage is usually eaten hot (one of the very few dishes eaten hot), has a lot of body and makes a very pleasant break to a cereal diet—a native view that I can whole-heartedly endorse.

### Milk.

Unlike other natives, *e.g.* the BeTswana, the BaSotho, except for herd-boys who drink direct from the udder, never use raw fresh milk. If they use it fresh, it is always boiled first. They prefer, however, to let it curdle, it goes better then with maize pap, etc., and also gives them a chance of extracting the butter fat first. This curdled milk is eaten as thick milk (*mafi*), whey (*hloea*) of mofehlo (churned mafi from which butter-fat has been extracted).

Butter is never eaten except by a few "Europeanised" BaSotho. It is, however, extensively used either to make soap or used as a cleanser, being used either by itself or when mixed with ochre. Mothers use it for their babies to protect and preserve the skin. It also has other uses. The Highlanders, who have more or less of a monopoly of it, trade it with the Lowlanders at a price of several shillings per pound.

Butter is preserved by roasting it over a slow fire, and treated in this

way lasts for years without getting offensively rancid. In the process of roasting some of it chars and settles out. This makes a very rich, almost nauseating substance, called bohoko, which is sometimes eaten in very small quantities.

In those families that have no milk, an artificial "milk" is sometimes made for the children to take as a relish with their maize breads (*bohobe ba lephokojoa*, etc.). It is called "chicken's milk." Mealies are cooked with a lot of water, and the whole left to ferment. When it begins to do so, the clean liquid above the maize precipitate is drained off and kept apart to be used as wanted. I am told this tastes very much like whey.

## Meat.

Meat is cooked by roasting, boiling or broiling. When skilfully prepared in the last way it is made very tender and appetising. The BaSotho do not sun-dry their meat to make biltong. They prefer their meat fresh, and so do most of their killing in winter when it will keep, but some of them are not as squeamish about eating it tainted as we are.

## General.

*Relishes.*—The BaSotho have practically no relishes, unless one adopt their attitude and call milk and spinach relishes as being things to be eaten with the main dish, *bohobe ba lephokojoa*. But they have no sauces and natural or indigenous flavourings. To-day, however, they use pepper, salt and curry as flavourings, where they can afford it, and a few onions or leeks where they grow them or can beg them.

Very few dishes are eaten hot. Bean or pea pottage is about the only one that is eaten hot at all frequently, and even so, as often as not is eaten cold. Should they be very hungry, people may eat *bohobe ba lephokojoa* as soon as it comes off the fire, but they usually let it cool first. (Tea is usually drunk hot.) This seems to be a custom born of circumstances, for with their lack of crockery and other utensils it is difficult to keep things hot and much easier to serve them cold. Besides which most of the Sotho foods taste better when eaten cold, and the BaSotho also claim that hot foods are bad for the teeth.

*Etiquette.*—Each family eats together *en famille*, parents and children share the same meal, the men eating out of one dish, women and children out of another, but when guests, other than intimate friends, are present men eat first, the others afterwards. Where the parents do not have a midday meal or are away from the village the children are allowed to help themselves to food, or sometimes even to cook for themselves some if there is nothing left over from the morning meal.

Meals are pleasant, sociable affairs. People chat and eat their food leisurely, and to bolt one's food is considered boorish and ill mannered. Before a meal, adults usually wash their hands, and at the end of it rinse out their mouths with fresh water. (These hygienic customs are being abandoned by the younger generations.) Contrary to general belief, the BaSotho usually take great care to keep clean dishes, milk pails, pots and other utensils connected with the preparation and consumption of food.

## APPENDIX V.

The following figures were collected by my assistant in respect of the amount of grain harvested by his neighbours in the winter of 1936. They are not complete, but they give a rough idea of the grain resources of each family (only Families Nos. 1–6 of Appendices I–III are cited) and how the returns of each vary. It was a fair season, but it will be noted these families scarcely reaped enough to keep themselves in food, let alone giving them the means easily to satisfy their other needs.

| Family. | No. of fields. | Return per field measured in bags. | No figures available. | Total No. of bags. |
|---|---|---|---|---|
| No. 1 | 8 | Maize: 9, 1, 1, 2. | | 13 |
| | | Wheat: 8. | 2 | 8 |
| | | K-corn: 2. | | 2 |
| No. 2 | 8 | Maize: 2, 2, 2, ½. | | 6½ |
| | | Wheat: | 2 | .. |
| | | K-corn: 1. | | 1 |
| | | Oats: | | .. |
| No. 3 | 4 | Maize: 4½, 2½, 1. | 1 | 8 |
| | | Peas: 1. | | 1 |
| No. 4 | 4 | Wheat: 1, 1½. | | 2½ |
| | | Peas: 2. | | 2 |
| | | Maize: | 1 | .. |
| No. 5 | 3 | Maize: 6, 1½, 1. | | 8½ |
| No. 6 | 3 | Maize: 3, ½. | 1 | 3½ |

*Note.*—Figures for No. 1 in respect of both this man's households. Each household would get a more or less equal share of the harvest, *i.e.* about half the above.

No. 2 had good wheat lands from which he would have reaped 8–10 bags between them had the crop not been destroyed by stray stock.

No. 3, the outstanding field, should have produced at least 2 bags. The peas come from part of one mealie field.

No. 4 was lent a land, from which she reaped the peas, by her mother. Her brother ploughed it for her.

No. 6's outstanding land should have produced at least 2 bags.

All the above would have had half a bag or so of peas or beans, especially Nos. 2, 4, 5, in addition to the rest of the crop.

A bag weighs, as filled by natives, about 220–230 lbs. of maize, and more in the case of wheat.

## APPENDIX VI.

Extract, page 41. Report on the *Financial and Economic Position of Basutoland*, January 1935. Cmd. 4907.

| Particulars. | 100 taxpayers of less than 5 years' standing. | 100 taxpayers over 5 and less than 10. | 100 taxpayers of 10. |
|---|---|---|---|
| 1. Number found at home . . | 32 | 40 | 70 |
| 2. Number found absent at: | | | |
| *a.* Gold mines . . . | 55 | 15 | 17 |
| *b.* Farms . . . . . | 1 | 14 | 2 |
| *c.* Miscellaneous labour in Union | 3 | 2 | 2 |
| *d.* Unknown and wanderers . | 6 | 19 | 5 |
| *e.* Dead . . . . . | 2 | 1 | 0 |
| *f.* Removed to other parts of Basutoland . . . | 1 | 9 | 4 |
| *g.* Total number absentees . | 68 | 60 | 30 |
| 3. Number concerning whom statistics were available . . | 93 | 75 | 90 |
| 4. Number concerning whom no statistics available . . . | 7 | 25 | 10 |
| 5. Number who have never worked in the Union . . . . | 6 | 13 | 29 |
| 6. Number who have worked in Union at one time or another . | 87 | 62 | 61 |
| 7. Average number of years spent at work in Union during lifetime (*vide* Para. 6) . . . | 1·44 | 4·45 | 6·50 |
| 8. Average number of years absentees have been away in Union (*vide* Para. 2*a*, *b* and *c*) . . | 1·20 | 2·00 | 1·75 |
| 9. Average number of stock owned: | | | |
| *a.* Cattle . . . . . | ·27 | 1·67 | 5·93 |
| *b.* Equines . . . . . | ·08 | 1·12 | 2·04 |
| *c.* Small stock . . . . | ·57 | 26·20 | 30·00 |
| 10. Number of taxpayers with no stock at all . . . . | 80·00 | 32·00 | 17·00 |
| 11. Average number of lands . . | ·22 | 1·25 | 3·12 |
| 12. Number of taxpayers with no land at all . . . . . . | 84·00 | 30·00 | 9·00 |
| 13. Average number of dependants . | ·67 | 2·93 | 5·86 |

## APPENDIX VII.

*Extracts from Annual Medical Reports*, 1928–37.

Cases dealt with in Government Hospitals and Dispensaries.

| Year. | Out-patients. | All forms Tuberculosis. | Pulmonary type. | Scurvy. | Pellagra. | Rickets. | Dysp. | Const. |
|---|---|---|---|---|---|---|---|---|
| 1928 | 46535 | 546 | 370 | 34 | .. | .. | ? | ? |
| 1929 | 41695 | 495 | 263 | 13 | .. | 7 | ? | 3102 |
| 1930 | 42304 | 531 | 295 | 21 | 4 | 3 | ? | 3124 |
| 1931 | 38737 | 369 | 261 | 34 | .. | 8 | 3124 | 3075 |
| 1932 | 44382 | 559 | 390 | 39 | 3 | 9 | 3173 | 3078 |
| 1933 | 40373 | 509 | 318 | 95 | 3 | 8 | 2985 | 2896 |
| 1934 | 43051 | 445 | 254 | 22 | 76 | 3 | 3007 | 3286 |
| 1935 | 45455 | 812 | 549 | 29 | 163* | 10 | 3441 | 3554 |
| 1936 | 54015 | 111 | 496 | 64 | 216* | 12 | 3333 | 3512 |
| 1937 | 72264 | 812 | 423 | 120 | 270* | 6 | 4432 | 6211 |

* Excluding 21, 35, 26 cases observed by private medical practitioners.

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# NEW RECORDS AND DESCRIPTIONS OF MARINE FISHES FROM PORTUGUESE EAST AFRICA.

By J. L. B. Smith.

(With two Text-figures.)

(Read March 15, 1939.)

## Family MALACANTHIDAE.

### *Malacanthus latovittatus* Lac.

1936. Weber and de Beaufort, Fishes Indo-Austral. Archip., vol. vii, p. 551, fig. 105.

Body elongate, anteriorly subcylindrical, posteriorly compressed. Snout more or less conical, dorsal profile of snout low and evenly convex from nape.

Depth 5·2, length of head 3·55 in length of body. Eye 6·7, snout 2·2, interorbital 3·7, and postorbital part of head 2·5 in length of head.

Posterior nostril slit-like. A strong flat spine on opercle, projecting beyond the hind margin of the operculum. Preopercle not serrate.

Mouth fairly large, almost horizontal, lips fairly thick, jaws subequal, maxilla not to eye, extends below two-thirds of distance from snout tip to eye. Villiform teeth in a narrow band in each jaw, laterally these teeth become more or less conical. Behind these are some smaller granular teeth. No information about gills, gill-rakers and other internal parts available.

D 51, long and low, originates above hind margin of operculum. No sharp definition of anterior spines, though the articulations in the first six rays are rather indefinite. Margin of dorsal gently convex, fin ends just short of caudal base. First ray 6·5, 5th 4·3, mid-rays longest 3·5 in head.

A 42 (or I, 41): inserted below pectoral tip, or the 12th dorsal ray. 1st ray 8·6, 3rd 6·3, anterior mid-rays longest 4·1 in head, thereafter graduated shorter. Edge of fin gently convex, fin ends slightly behind end of dorsal base. Pectoral subfalcate, 1·8 in head, tip reaches above anal origin. Ventrals inserted below pectoral base, 3·0 in head. Caudal

almost truncate, very slightly emarginate, lobes slightly produced. Fins not scaly basally.

Scales small, ctenoid. Lateral line arched from shoulder, drops to middle of side and runs more or less straight on the peduncle. L.l. 132, l.tr. $\frac{10}{47}$, 7 series of scales across cheek. Chin, snout, and interorbital naked, scales on head extend to above hind margin of preopercle, not to eye. Preopercle flange broadly naked. A naked patch above pectoral axil.

*Colour* (preserved, according to colour sketch made by Senhor Peão Lopes, junior).—Body of a blue shade. From above the eye along the nape tapering to a point halfway along the dorsal base, dark brown. A dark brown longitudinal stripe, wider than eye, running from above the pectoral base to the caudal, continuous on caudal where it widens and bifurcates, the narrower upper and lower arms enclosing a rounded white space about as big as the eye, bordered behind by the hind margin of the caudal. Dorsal brown with white edge. Anal white. A blue-green area on the side of the chest. Operculum greenish. Snout blue. Pectorals and ventrals light.

*Length.*—373 mm.

*Locality.*—Coast near Inhambane.

A single specimen, stuffed, in the Museu Alvarez da Castro, Lourenço Marques. This family has not previously been recorded from South Africa. The species described above has been recorded from Mauritius and beyond.

## Family LUTIANIDAE.

### *Glaucosoma peaolopesi* n. sp.

(Text-fig. 1.)

Body very compressed, more or less ovate. Dorsal profile of snout steep from nape. Nape prominent, almost gibbous, some degree of simocephaly. Depth 2·1, length of head 3·1 in length of body. Eye 5·0, snout 6·5, interorbital 3·2, and postorbital part of head 2·0 in length of head. Mouth moderate, maxilla expanded posteriorly extends below hind margin of eye. Mouth very oblique, subvertical, lower jaw projects. Supramaxilla apparently present. Teeth in broadish villiform bands in each jaw, the outer enlarged series caniniform. Palatal teeth not visible, probably hidden by mounting. Preopercle margin almost straight, vertical, serrate. A strong flat spine on opercle. No information available about gills and gill-rakers or other internal parts.

D X, 17: inserted in advance of hind opercular margin. Spines short and stout, heteracanth, increase from the first to the fifth, thereafter

subequal. First spine 8, 2nd 5·5, 3rd 4, 5th 3·8 in head. Base of spinous dorsal 2·7 in body. Soft dorsal elevated, anteriorly falcate, rays broad and heavy. First ray 4·4, 2nd 2·8, 3rd and 4th longest, 2·7 in length of body; remaining rays graduated shorter, last one-third of first. Edge of fin gently convex behind anterior rays. Base of soft dorsal 1·2 in base of spinous. Soft dorsal densely scaly at base.

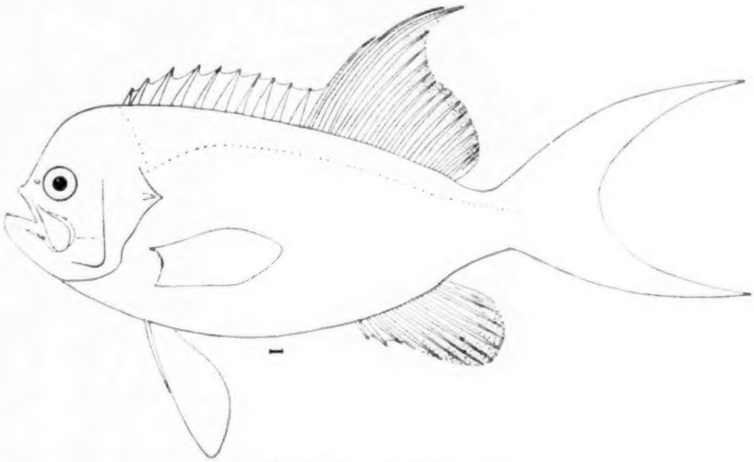

FIG. 1.—*Glaucosoma peaolopesi* n. sp.
The line below the figure represents 1 cm. The dots on preopercle and shoulder indicate number and disposition of scale rows.

A III, 9: inserted below the 6th dorsal ray, spines short and stout, 1st 7, 2nd 4, 3rd 3·6 in length of head. Rays longer than spines, fin gently convex. First ray 2·1, 5th 1·5, and last 2·6 in length of head. Fin densely scaly basally. Pectoral rounded, 1·25 in head. Ventrals inserted below pectoral base, 1·17 in head. Caudal very deeply lunate, lobes almost filamentous. Pectorals, ventrals, and caudal scaly at bases.

Lateral line anteriorly curved, runs parallel with dorsal profile, reaches caudal base well up on dorsal surface of peduncle. Scales ctenoid, rough, covering whole body and head including maxilla and chin. Auxiliary scaling present over most of the body. L.l. 52–53, l.tr. $\frac{9}{25}$, 11 series across cheek (vertical series between hind margin of maxilla and preopercle margin).

*Colour* (just after death, from notes and sketch made by Senhor A. Peão Lopes).—Pinkish, with yellow suffusion over body. Pectoral, anal, tips of dorsal and all of caudal lobes yellow. Central patch on caudal pink.

*Length.*—470 mm.

*Locality.*—On the coast between Delagoa Bay and Inhambane, taken on a line.

Type (a stuffed specimen) in the Museu Alvarez da Castro, Lourenço Marques. Named in honour of Senhor Alberto Peão Lopes of that Museum.

A most interesting specimen, the first species of this genus reported from the African region. The other species are known from the Australian region. In some respects this specimen merits generic distinction from the Australian forms, but that may be left until a complete specimen becomes available.

It may be noted that relatively many Lutianid species are being discovered in our region at the present time. Some, which are plentiful in Delagoa Bay, have only recently been recorded.

*Gnathodentex aurolineatus* Lac.

1936. Weber and de Beaufort, Fishes Indo-Austral. Archip., vol. vii, p. 348, fig. 72.

Body oblong-ovate, fairly compressed. Dorsal profile of snout but little elevated, gently and evenly convex. Snout sub-conical.

Depth 2·6, length of head 3·0 in length of body. Eye equal to snout, 3·0, interorbital equal to postorbital part of head, 2·7 in length of head. A broad flat triangular spine on opercle, not extending beyond opercular margin. Preopercle margin slightly rough but not denticulate. Posterior nostril circular. Gill-rakers short and stout, 6 on lower limb of anterior arch. Preorbital very shallow, depth 3 in eye.

Mouth moderate, horizontal, maxilla extends to below midway between nostrils and anterior border of eye. Maxilla with a strong externally roughly granulated or serrated bony ridge, the outer face of which remains uncovered by the preorbital even when the mouth is closed. Lips fairly thick. Four fairly large close-set curved caniniform teeth in the front of the upper jaw, a similar smaller one more widely spaced on each side. A prominent outwardly flaring canine on each side in the front of the lower jaw with smaller curved teeth between. A band of villiform teeth in each jaw, narrowing laterally, where those in the outer row are conical and somewhat enlarged. Vomer and palatines edentate.

D X, 10: inserted over hind preopercle margin. Spines fairly slender. First spine 7·3, 2nd 3·3, 4th and 5th subequal, longest, 2·6 in head, remainder graduated very slightly shorter. Soft rays higher than last spine, 1st ray 2·5, 5th longest 1·9 in head. Edge of soft fin strongly convex.

A III, 9: inserted below the base of the 2nd dorsal ray. 1st spine 6, 2nd 3·4 in head, 3rd slightly longer. Soft rays longer than spines, 5th

longest 2·6 in head. Edge of fin convex. Pectoral 1·2 in head. Ventrals 1·5 in head, 1st ray somewhat extended. Caudal moderately forked.

Scales feebly ctenoid, moderate. Lateral line evenly curved from shoulder, follows dorsal profile. L.l. 75, l.tr. $\frac{6}{20}$, 5 series of scales on cheek. Scales on head extend to above hind margin of pupil. Interorbital, snout, chin and preopercle flange naked. Soft dorsal and anal naked, with very low sheath.

*Colour.*—More or less uniform brown with traces of numerous light longitudinal streaks. Caudal lobes darkish.

*Length.*—230 mm.

*Locality.*—Inhaca Island, Delagoa Bay.

This specimen was taken by a net in shallow water. The species is evidently not common, since the fishermen did not recognise it.

This is the first record of this genus and species from South Africa. It has been reported from Mauritius.

## Family NEMIPTERIDAE.

### Genus *Nemipterus* Swainson.

1933. Fowler (Bull. U.S. Nat. Mus., vol. xii, p. 128) included *filamentosus* Valenciennes in *Dentex* Cuv., and would not accept Swainson's genus founded on *filamentosus*, because Cuvier and Valenciennes' figure (Hist. Nat. Poiss., vol. vi, pl. 155, 1830, *fide* Fowler) shows five rows of scales on the cheek. The general diagnosis of *filamentosus* does not agree with *Dentex*, and Weber and de Beaufort (Fishes Indo-Austral. Archip., 1936, vol. vii, p. 354) record that a recent re-examination of the type of *filamentosus* has shown that it has only three rows of scales on the cheek. Swainson's genus thus becomes valid and has priority over *Synagris* Günther.

Fowler considers *Nemipterus* (=*Synagris* Günther) a Sparid, Weber and de Beaufort a Lutianid genus. It is closer to the latter family, but Regan's classification is followed here, giving family rank to *Nemipterus*, which is fully justified by the characteristic structure of the mouth.

This genus has not previously been recorded from South Africa, though numerous species range through the Indo-Pacific. One species has recently been found in Delagoa Bay.

### *Nemipterus mulloides* n. sp.

(Text-figure 2.)

Body elongate, ovate, compressed. Dorsal profile gently sloping from nape almost uniformly convex, slight prominence before eye. Inter-

orbital convex. Depth 3·4, length of head 3·1 in length of body. Depth of head through preopercle flange equal to length of head less half width of opercle. Eye horizontal diameter 4·0, vertical diameter 4·8, snout 2·6, interorbital 4·0, postorbital part of head 2·6 in length of head. Preorbital smooth, very faintly emarginate over hind end of maxilla. Preorbital with a dense series of parallel subvertical subcutaneous tubules, the posterior branching. (The naked preopercular limb similarly striated.) Least depth of preorbital just more than vertical diameter of eye, slightly

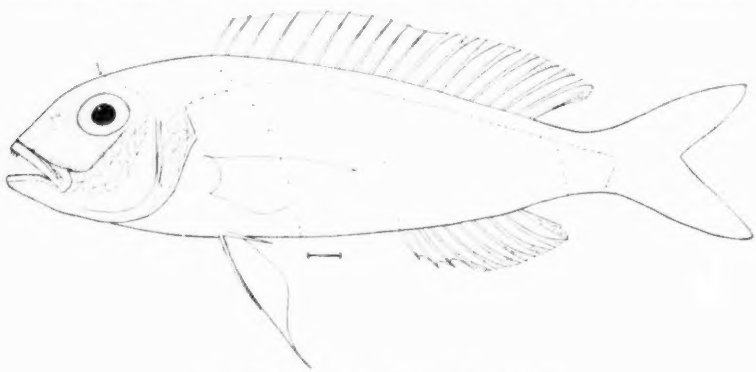

FIG. 2.—*Nemipterus mulloides* n. sp. (Type.)

The line below the figure represents 1 cm. The small arrow shows anterior margin of scaling on head. The rows of dots on the body show number and disposition of scale rows.

less than longitudinal diameter. Hind margin of preorbital when produced cuts dorsal profile half an eye diameter before the origin of the dorsal fin. Nostrils small, circular, close together, at level of centre of eye, slightly nearer anterior margin of eye than snout tip. Preopercle margin quite smooth, naked flange across widest part about as wide as scaly part of cheek. A flat spine, mostly concealed, on the opercle.

Mouth fairly large, slightly oblique, lower jaw shorter than upper, upper canines visible when mouth closed. The maxilla not covered by preorbital, extends to below slightly before anterior margin of eye. Length of maxilla from snout tip 2·6 in length of head. In the upper jaw anteriorly seven enlarged curved caniniform teeth, the outer longest graduated shorter inwards. These upper teeth are at least four times the size of the outer anterior teeth in the lower jaw, which teeth although enlarged could hardly be regarded as canines. Twenty slender sharp curved teeth in the outer lateral series on each side of the upper jaw. Sixteen similar teeth in the outer lateral series on each side of the lower jaw. An inner band of villiform teeth in each jaw, deepest anteriorly.

Gill-membranes separate and free from isthmus. Seven short tubercular spinescent gill-rakers on lower margin of anterior arch. Gill-filaments moderate, longest two-thirds of eye.

D X, 9: inserted behind hind margin of head above pectoral axil. Spinous portion slightly longer than soft. Spines slender, membrane scarcely incised. First spine 4·8, 2nd 4·5, 3rd 4·2, 4th 3·5, 5th to 10th subequal 3·1 in length of head. Soft rays slightly higher than spines, 1st to 8th subequal 2·6 in head, last ray slightly shorter. Edge of fin gently convex. Base of dorsal 1·7 times head.

A III, 7: inserted below first dorsal ray, 1st spine 5·7, 2nd 3·9, 3rd 3·5 in length of head. 1st to 6th rays subequal 2·8 in head, last ray slightly shorter. Base of anal 1·6 in length of head. Pectoral 1·4 in head, equal to distance from snout tip to hind margin of preopercle. Ventral 1·2 in head, first ray filamentous but does not reach anal origin. Ventral axillary scale one-third of fin. Caudal deeply forked; peduncle fairly slender, least depth of peduncle 3 in head.

Scales ctenoid, fairly large; vertically elongate. The second and third series below the lateral line largest, 1·8 times as deep as wide. Lateral line runs almost parallel with dorsal profile, well up on dorsal part of peduncle. Lateral line tubes bifurcate posteriorly into two long branches. L.l. 49, l.tr. $\frac{4}{9}$ from just in advance of dorsal origin. Fifteen predorsal scales, scaling extends above centre of eye. Three series of scales down cheek; there is a fourth series of very narrow scales all but hidden beneath the hind·preorbital margin. Three large scales across widest part of opercle. Interorbital, snout, preorbital, chin and preopercle flange naked. Dorsal and anal fins naked; no basal sheath. Caudal densely scaly, inner lobar margins naked.

*Colour.*—More or less uniform silvery rose, slightly lighter below. A faint opercular blotch, preopercle flange darker. Fins very light yellow, fades on preservation. With preservation there develops an opalescent streak along each scale row below the lateral line.

*Length.*—215 mm.

*Locality.*—Delagoa Bay—taken on a line in about 4 fathoms.

*Type.*—A ripe female, in the Albany Museum.

Several smaller specimens from the same locality, 100–120 mm. in length are doubtfully referred to this species. Positive identification of juveniles in these fishes is exceedingly difficult, indeed the adults do not differ widely between the different species. These juvenile specimens differ chiefly in the depth, which is 3·7–3·9 in body, and in the much shallower preorbital, which is 1·7 in the horizontal diameter of the eye.

*N. mulloides* belongs to the sub-group in this genus with canines in the upper jaw only, and is related most closely to *mesoprion* Bleeker, which has

been recorded from Singapore and Sumatra. *N. mulloides* differs from *mesoprion* chiefly in the absence of serrations from the preopercle margin, the much broader interorbital, the much longer snout, shorter maxillary, and in the absence of caudal filaments. Also *mesoprion* has a very much narrower naked preopercle margin and more transverse series of scales.

I wish to express my gratitude for the great kindness and assistance received from the Provincial Administration of Mocambique and from the Museum and the Port Authorities at Lourenço Marques during a recent collecting visit. Also to the Research Grant Board of South Africa (Carnegie Fund) for financial assistance.

ALBANY MUSEUM,
GRAHAMSTOWN,
*February* 1939.

# THE QUARTZ HORIZONTAL INTENSITY MAGNETOMETER. (Q.H.M.)

By K. W. Simpson and A. M. van Wyk.

(Communicated by A. Ogg.)

(Read April 19, 1939.)

In a paper * by Ogg, Gotsman and Simpson giving a comparison of two instruments, Q.H.M. $No._{29}$ and Q.H.M. $No._{30}$, it was shown that there was excellent agreement between the variometer base-line values as determined by them. The following statement was made with regard to their suitability for field work:—

"If it can be shown that the torsion coefficients and the magnetic moments of these instruments remain sufficiently constant with travel and with time to give consistent results, they will have a great advantage over the usual form of portable magnetometer."

Since the publication of the above-mentioned paper it has been possible to make an exacting test to answer this question.

One of us (K. W. S.) took $Q.H.M._{29}$ into the field for a period of eight months for magnetic survey observations. The survey during this period entailed transport in a motor van over 9000 miles of average South African roads. In all about 1700 observations were made at the 27 secular variation stations established during the tour. The other of us (A. M. van Wyk) made about 160 determinations, during the same period, of base-line values at the observatory with $Q.H.M._{30}$ along with the determinations with the C.I.W. Magnetometer No. 17.

The Table on p. 224 shows the comparison of 4 sets of observations taken before the tour with 4 sets taken after the tour.†

These results give a complete answer to the question of the suitability of these instruments for field work.

The mean corrections for torsion were negligible.

The torsion corrections given in the former paper should read 0·07 $\gamma$ for $Q.H.M._{29}$ and 0·02 $\gamma$ for $Q.H.M._{30}$ in place of 0·7 and 0·2 given in the paper.

* Trans. Roy. Soc. S. Afr., vol. xxvi, p. 395.

† It was intended to take two sets of readings during the week preceding the meeting of the Society, but owing to strong magnetic storms during that week these were deferred until after the meeting.

COMPARISON OF THE LA COUR QUARTZ HORIZONTAL MAGNETOMETERS, NOS. 29 AND 30.

| Q.H.M. | Date. | Mean Value $H_0$ | Diff. $H_0(30) - H_0(29)$. | Date. | Mean Value. $H_0$. | Diff. $H_0(30) - H_0(29)$. |
|---|---|---|---|---|---|---|
| | | $\gamma$ | $\gamma$ | | $\gamma$ | $\gamma$ |
| 30 | 11/5/38 | 14440·7 | +2·1 | 11/4/39 | 14421·7 | +1·8 |
| 29 | 11/5/38 | 14438·6 | | 11/4/39 | 14419·9 | |
| 30 | 3/6/38 | 14438·4 | +0·6 | 13/4/39 | 14418·4 | +0·8 |
| 29 | 3/6/38 | 14437·8 | | 13/4/39 | 14417·6 | |
| 30 | 8/7/38 | 14439·8 | +0·4 | 21/4/39 | 14421·3 | −0·4 |
| 29 | 8/7/38 | 14439·4 | | 21/4/39 | 14421·7 | |
| 30 | 29/7/38 | 14435·4 | +0·4 | 24/4/39 | 14421·0 | +0·7 |
| 29 | 29/7/38 | 14435·0 | | 24/4/39 | 14420·3 | |
| | | Mean . | +0·9 | | Mean . | +0·7 |

The Q.H.M.$_{29}$ has been used throughout this survey to give diurnal curves of Horizontal Intensity and of Declination of the kind shown in the former paper. This method has proved of great value in establishing the difference between magnetic values at the field stations and at the magnetic observatory for the purpose of secular variation determinations. The results of the field survey will form the subject of another communication.

# A NEW MITE ATTACHED TO THE SEX ORGANS OF SOUTH AFRICAN MILLIPEDES.

By R. F. Lawrence, Ph.D., Natal Museum, Pietermaritzburg.

(With three Text-figures.)

(Read April 19, 1939.)

During the last five years the writer has had occasion to dissect out the gonopods of numerous genera of South African millipedes for purposes of identification, and has on several occasions noted the presence of tiny mites in connection with the gonopods. The genera concerned were *Chersastus*, *Doratogonus*, and *Ardiophyllum*. About 20 specimens of minute mites from a species of the last-named genus in the Natal Museum do not differ in any way from the Deutonymphs described in this paper. At the time these minute mites were merely noted as occurring on and between the complicated structures of the gonopods, and were taken for the larval stages of the external mite parasites which are known to occur on some genera of millipedes. They were thus not examined in detail.

During January 1939 seven examples of the large Spirostreptid, *Doratogonus flavifilis* Peters, were obtained from the Eastern Transvaal at Nelspruit, four of these specimens being males. The gonopods of one of the males having been removed *in toto*, together with the membrane surrounding them, a large cluster of minute mites was observed near the subjoined bases of the gonopods; this cluster was situated on the aboral surface—that is, the aspect facing the posterior end of the millipede. The mites were immediately sketched *in situ* (fig. 1), before many of them had become detached. It will be noted that no mites were attached near the free distal end of the gonopod but only to the basal halves; neither could any be seen on the oral (anterior) surface of the gonopods. These mites occurred in the same position on all four of the males, being numerous in three specimens, 54, 160, and 190 being counted, while in the case of the fourth male only eight specimens were counted. The vulvae of the three female specimens behind the second body segment, and the openings of the penes of the males on the same segment, were examined without finding further specimens.

These mites therefore must have entered through the narrow opening

between the apices of the gonopods and their surrounding membranous sheath, passing upwards and slightly forwards for a distance of about 5 mm. before arriving at the final place of attachment to the bases of the gonopods. The mites appear to have sought out the most sheltered parts of the sex organs of the host, congregating most thickly in the crevices

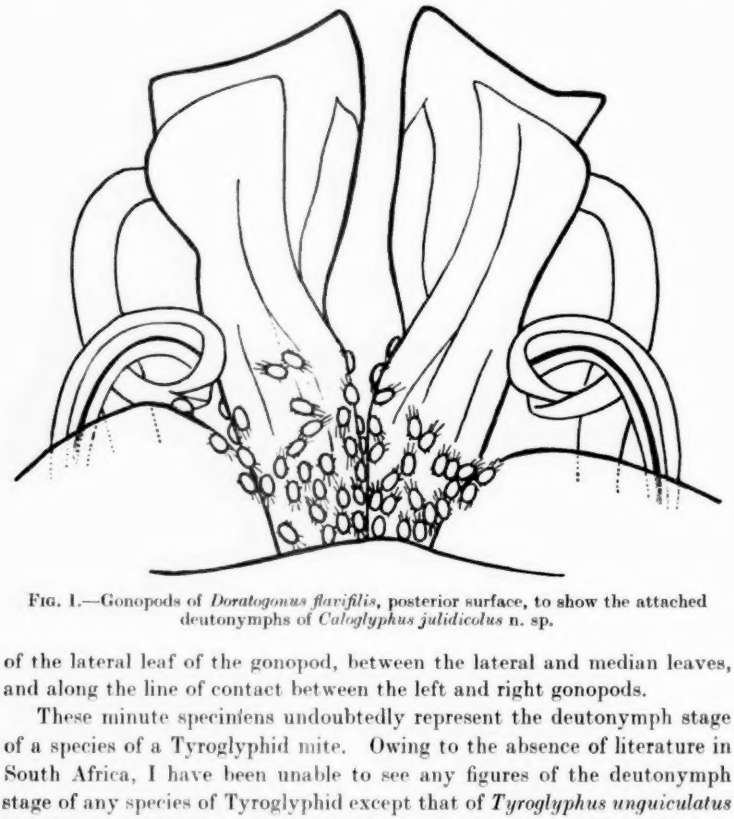

**Fig. 1.—Gonopods of *Doratogonus flavifilis*, posterior surface, to show the attached deutonymphs of *Caloglyphus julidicolus* n. sp.**

of the lateral leaf of the gonopod, between the lateral and median leaves, and along the line of contact between the left and right gonopods.

These minute specimens undoubtedly represent the deutonymph stage of a species of a Tyroglyphid mite. Owing to the absence of literature in South Africa, I have been unable to see any figures of the deutonymph stage of any species of Tyroglyphid except that of *Tyroglyphus unguiculatus* Vitzthum, in Kükenthal's Handbuch der Zool., Bd. iii, H. 2, Lief. 1, Acari, p. 84, fig. 110, 1931. This species, according to the author, attached itself to flying insects. Sketches of the dorsal and ventral aspects of the mite were sent to Dr A. C. Oudemans of Arnhem, Holland, who was so kind as to identify the genus to which it belonged, *Caloglyphus* Berlese. I take this opportunity of tendering my best thanks to the distinguished Dutch acarologist for the time and patience he has expended on my behalf.

As no species of *Caloglyphus* have been recorded from Myriopoda, and as this form of *Caloglyphus* is presumably found only on millipedes, I propose to regard it provisionally as a new species, the deutonymph of *Caloglyphus julidicolus*.

Gen. *Caloglyphus* Berlese.

*Caloglyphus julidicolus* n. sp.

Some of the 54 specimens from one of the males of *Doratogonus flavifilis* were mounted and figured. The bodies of these mites measured 240 $\mu$ in

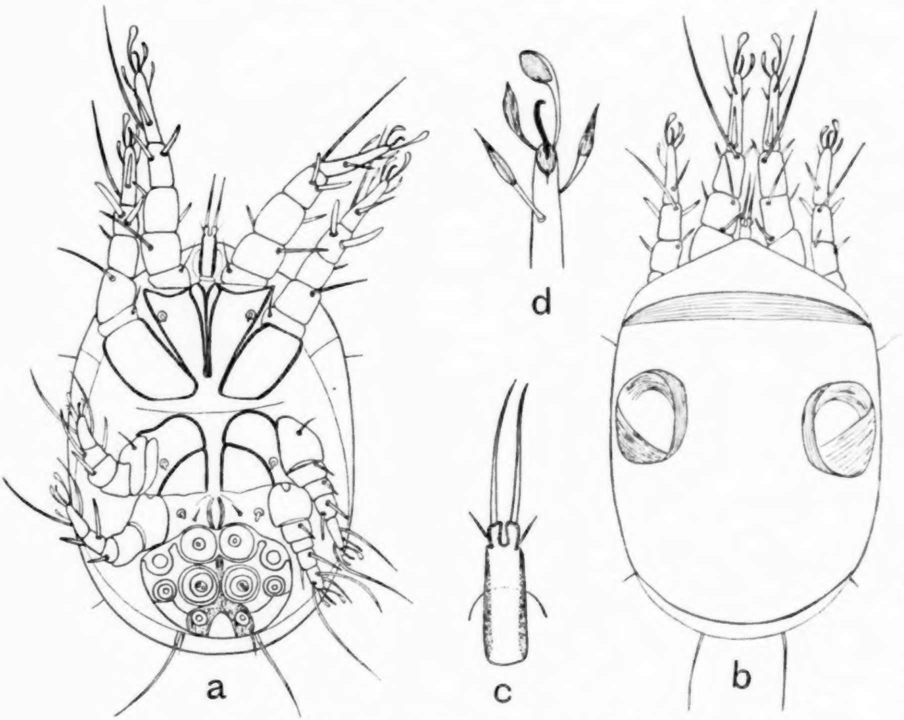


FIG. 2.—*Caloglyphus julidicolus* n. sp. Deutonymph.
*a*, ventral surface; *b*, dorsal surface; *c*, apex of tarsus I from below; *d*, mouth parts from below.

length and 210 $\mu$ in width, the legs not being included in the measurement. The largest specimen taken, from one of the other millipedes, was 358 $\mu$ in length and 260 $\mu$ in width.

*The dorsal surface* (fig. 2, *b*) appears to be without spines, but in some specimens a large oval pocket-like depression, the oil gland, can be seen near each side. These pockets are defined by a chitinous oval ring, their outlines being therefore darker than the remainder of the body, but the glands themselves appear as conspicuous light circular patches; these circular patches can be readily seen from the ventral side showing through the body. Seen from above the pockets appear to be partly covered on their lateral and medial sides with a crescentic membrane. The structure of these glands is not always well defined and in many specimens they cannot be clearly seen. In others, however, they are very conspicuous. *Ventral surface.* Seen from below (fig. 2, *a*), the deutonymph resembles fairly closely that of *Tyroglyphus unguiculatus* Vitzthum (*loc. cit.*, p. 84, fig. 110). It differs markedly, however, in the much longer anterior legs which are proportionately and actually much longer than the anterior ones, while in Vitzthum's figure the posterior and anterior legs of *T. unguiculatus* are equally reduced. The attachment plate of the opisthosoma bears four pairs of suckers, but the size of these suckers in proportion to each other differs markedly from those of *T. unguiculatus*, especially in respect of the anterior pair just behind the rudimentary genital opening, which are very much larger than the same pair in *T. unguiculatus*. A circular chitinous ring on the outer side of each anterior sucker and just above the lateral sucker of the second row, very closely resembles the other suckers, having a darkened centre in some specimens. After examining a large number of specimens, however, I have come to the conclusion that it is not a sucker but a pattern of the chitinous plate. If it should prove to be a sucker the plate would bear 10 instead of 8 suckers, an unusual condition in Tyroglyphidae. The very thin, completely transparent plate covering the suckers (fig. 3) is shaped differently from that of *T. unguiculatus*; it overlaps a considerable portion of the fourth pair of legs and also the posterior end of the rudimentary genital opening. A small spine and a stout papilla on each side of the rudimentary genital opening and a papilla on each of coxae I and III is present, as in *unguiculatus*. A rudimentary anal opening seems to be present but cannot be clearly seen.

The gnathosomal appendages (fig. 2, *c*) resemble those of *T. unguiculatus*, except that the basal piece is longer; at its apex there is a pair of long slender spines, with a minute hair on each side of and a little below the insertion of these spines. There is no trace of a second similarly formed structure lying above this plate as is figured for *T. unguiculatus*.

The suture dividing the anterior from the posterior coxae is slightly procurved rather than slightly recurved as in *T. unguiculatus*. The two spines on the underside of tibia II are much stouter than the same spines

in tibia I; the difference is more marked in *C. julidicolus* than in *T. unguiculatus*. The apex of tarsus I as in fig. 2, *d*, seen from below and strongly enlarged.

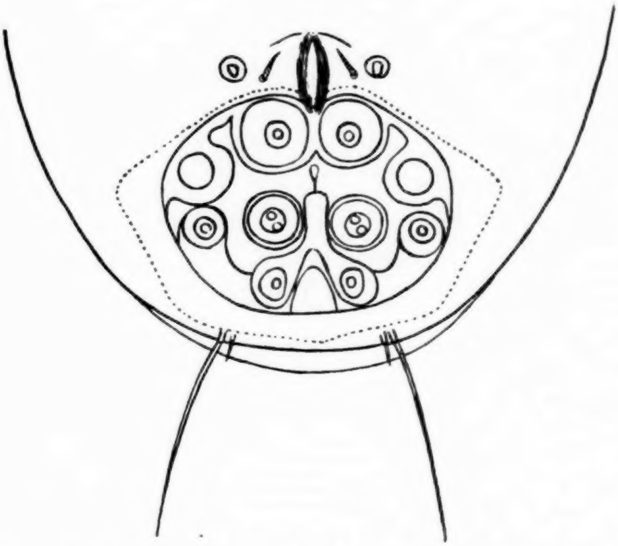

FIG. 3.—*Caloglyphus julidicolus* n. sp. Opisthosoma of deutonymph, ventral surface; transparent plate covering the sucker plate shown in dotted outline.

### *Remarks on the Ecology of the Deutonymph.*

The Deutonymph of the Tyroglyphidae, as is well known, is a stage appearing under conditions which are not as yet fully understood. It is interposed between the Protonymph and Tritonymph stages. According to Vitzthum in his comprehensive and detailed monograph on the Acari which has already been quoted, the deutonymph may represent a travelling stage (*Wandernymph*), or, as in *Glycyphagus*, a resting stage (*Dauernymph*). In some genera, such as *Tyroglyphus* and *Chaetodactylus*, both stages may be represented, the resting stage being, however, non-motile and differing in its structure from the travelling stage deutonymph.

The deutonymph of *C. julidicolus* is morphologically a travelling stage deutonymph. The host millipede, *Doratogonus flavifilis*, has a wide distribution along the east coast of Africa from Zululand to Mozambique, and would be a good vehicle for enlarging the distribution of the mite, or

transporting it from one place to another; these large active Spirostreptids must cover considerable distances in their wanderings, and, as is well known, the males are more active than the females. The host would also provide a means of transference to another millipede or of escape to the outside world on the occasions during which copulation takes place. According to the observations of the writer (see p. 234 of this Journal), mating takes place in another species of *Doratogonus* (*D. setosus uncinatus*) during the summer months, from October to February or March, so that many such opportunities would arise. From an ecological viewpoint, on the other hand, the position the mite has chosen for attachment would be an ideal one for passing through an inactive resting stage. Under unfavourable conditions of heat and drought the gonopods, closely invested by a membranous sheath which is again deeply imbedded in the moist body-cavity of the millipede, would provide an ideal retreat.

### *Remarks on the Feeding of the Deutonymph.*

Small clusters of the deutonymphs removed from the sutures and crevices of the gonopods were seen to be entangled in a semi-transparent sheet of irregular form which appeared to consist of coagulated liquid. Parts of this sheet were transparent and other parts finely granular, and this may perhaps represent masses of sperm which are found in considerable quantities on the gonopods of some Spirostreptid millipedes immediately after copulation. Naturally no solid sperms can be recognised in these structures taken from specimens which have been immersed for a considerable period in alcohol, but the general appearance of the substance, with aggregations of minute solid particles in it, does suggest that it may be liquid sperm which has become solidified by the action of alcohol.

While there is no evidence to suggest that the mites actually feed on the seminal fluid, such a possibility should be kept in mind. The rudimentary condition of the gnathosome structures excludes the possibility of the deutonymphs feeding on solid matter, or even ingesting the solid non-motile sperms of the Spirostreptids, but they may be able to imbibe the nutritious fluid in which the sperms are bathed. Vitzthum in his monograph suggests that some process of feeding during the Deutonymph stage may take place when he says (p. 110), "Solche Deutonymphae vor der Häutung zur Tritonympha eine Substanzvermehrung zeigen, die auf eine Nahrungsaufnahme, wie sie sonst für jede Häutung nötig ist, schliessen lässt."

If the pair of slender spines attached to the basal plate of the gnathosoma were hollow they should be able to suck up liquid by capillary attraction. Seen under high power of the microscope, however, they appear as ordinary

simple and solid spines (fig. 2, *d*), and it is therefore more likely that, as Vitzthum suggests, some kind of mouth opening exists in the deutonymph stage.

*Summary.*

The deutonymph stage of a new form of Tyroglyphid mite is described. Large numbers of these deutonymphs were found attached to the base of the gonopods of several males of *Doratogonus flavifilis*, and have been noted on the same organs in other genera of millipedes. Some suggestions are made with regard to the ecology and feeding habits of these mites.

# NOTES ON THE HABITS OF TWO MITES LIVING ON SOUTH AFRICAN MILLIPEDES.

By R. F. Lawrence, Ph.D., Natal Museum, Pietermaritzburg.

(Read April 19, 1939.)

In 1906 Trägårdh discovered two species of mites living on a genus of Spirostreptid millipede in Natal, and described these as *Neomegistus julidicola* and *Paramegistus confrater* (1). A year later, in a further paper (2), he gave an account of the biology and development of these mites. During the years 1935–1937 I was able to collect large numbers of both these species of mites from millipedes living in undisturbed bush at the Bluff, Durban, less than a mile from the sea. I was able to satisfy myself that the proper host of these mite parasites is the large blackish-brown millipede, *Doratogonus setosus* (Vog.), and I have no doubt that this is the species of millipede referred to when Trägårdh writes of the "great very dark-coloured Julidae on which *Neomegistus* occur" (2, p. 24). These "Julidae" can probably all be referred to this one species which is the commonest of the large Spirostreptid millipedes in Natal and has a wide distribution beyond the borders of the province. The specimens from which I was able to collect mites belong to a subspecies differing slightly from the typical *D. setosus* and described as *D. setosus uncinatus* by Attems (3). This millipede occurs in great abundance in the thick bush of the Bluff at Durban, where it can be seen during the summer months actively walking over the ground or climbing along the branches of shrubs and bushes. It is a comparatively easy matter to collect 50 of these Spirostreptids in the space of half an hour during November, especially after rain. The other smaller "bright scarlet-red Julide" mentioned by Trägårdh in his paper is undoubtedly a species of the genus *Chersastus*, probably *C. annulatus*, which is also abundant in the locality mentioned. These two millipedes together with the Oniscomorph, *Sphaerotherium giganteum*, are the three commonest millipedes at the Bluff, and all three climb trees.

Trägårdh states that he was never able to find either *Neomegistus* or *Paramegistus* on *Chersastus*. I have only found *Neomegistus* on two hosts other than *Doratogonus setosus uncinatus*; a single adult ♀ has been taken from *Chersastus annulatus* at the Bluff, Durban, though I have examined a great many specimens of various species of *Chersastus* at different times;

in the second place three adults (2 ♀♀ and a ♂) were taken from a small ♀ millipede not related to either *Chersastus* or *Doratogonus* at Estcourt, Natal. These are in all probability abnormal occurrences and may be regarded as stragglers from the true host.

*Paramegistus confrater* I have been able to find on only one other millipede besides *Doratogonus setosus*, a ♂ of *Poratophilus diplodontus* Attems, 5 specimens having been taken from an individual at Barberton, Transvaal, in January 1939.

Mating in the millipede *Doratogonus setosus uncinatus* takes place during the summer from October to March, and I always found specimens of both sexes at the Bluff during these months. As Trägårdh has already noted, the two species of mites in the adult form are only found on their host millipede during the summer months; in October and November of 1936 I collected 54 specimens of *Doratogonus setosus uncinatus*, and carefully counted the number of *N. julidicola* and *D. confrater* on each specimen. To prevent the parasites from falling off, each millipede was tightly corked in a large glass tube and its sex recorded. The sexes in this millipede are easy to distinguish by means of a number of well-marked characters. Apart from the obvious differences of the sex organs the male millipede is slenderer, the texture of the body rings more glossy, and there is a slight hump behind the collum on the dorsal surface; the male is also in general more active, and its walk more rapid. The presence of gonopods and the padding of the feet were, however, always the criteria used in assigning the sex of the millipede in question.

Of the first batch of 24 millipedes examined in October, 12 were males, 7 fully developed females, and 5 were "neutral" preadult specimens; these last, though not or very slightly smaller than the adults, could not be described as fully developed owing to the slight differences in colouring which distinguishes the stage just preceding the adult form. A further batch of 30 individuals collected in November consisted of 15 adult males, 11 adult females, and 9 preadult forms. Thus in all 27 adult males, 18 adult females, and 9' preadult forms were examined. Of the 27 males examined all were parasitised by *Neomegistus julidicola* (a total of 91 adult mites of both sexes), and all except two by *Paramegistus confrater* (a total of 103 adult mites of both sexes). The specimens of *P. confrater* are much the smaller and the lighter coloured of the two forms of mites; they look very much like the immature stages of the robust and darker-coloured *N. julidicola*, which for some time I took them to be. Quite a different state of affairs was revealed when the female millipedes were examined; 11 of the 18 had no mite parasites at all, and the remaining ones shared 14 specimens between them, all of these being *Paramegistus confrater*.

With regard to the 9 preadult millipedes, 4 were not parasitised, while

the remainder had a total of 6 specimens of *Paramegistus confrater*. The results can be tabulated thus:

MALE MILLIPEDES.

| | *Neomegistus.* | *Paramegistus.* | Total No. of *Mites.* |
|---|---|---|---|
| 1 | 3 | 1 | 4 |
| 2 | 5 | 6 | 11 |
| 3 | 1 | 5 | 6 |
| 4 | 5 | 4 | 9 |
| 5 | 1 | 1 | 2 |
| 6 | 8 | 0 | 8 |
| 7 | 6 | 5 | 11 |
| 8 | 9 | 3 | 12 |
| 9 | 3 | 1 | 4 |
| 10 | 6 | 2 | 8 |
| 11 | 2 | 2 | 4 |
| 12 | 4 | 3 | 7 |
| 13 | 5 | 12 | 17 |
| 14 | 4 | 4 | 8 |
| 15 | 3 | 3 | 6 |
| 16 | 1 | 6 | 7 |
| 17 | 3 | 5 | 8 |
| 18 | 1 | 1 | 2 |
| 19 | 3 | 6 | 9 |
| 20 | 1 | 7 | 8 |
| 21 | 1 | 4 | 5 |
| 22 | 1 | 7 | 8 |
| 23 | 4 | 0 | 4 |
| 24 | 3 | 2 | 5 |
| 25 | 3 | 2 | 5 |
| 26 | 4 | 7 | 11 |
| 27 | 1 | 4 | 5 |
| Total | 91 | 103 | 194 |

It thus appears that while on the male millipedes the average number of mites of both species was more than 7, the average found on the female millipedes was less than 1. Still more remarkable, one of the species of mites (*Neomegistus*) though abundant on the males was entirely absent in the female and preadult mites. The few specimens of *Paramegistus confrater* found on some of the females (less than half the total number examined) could be accounted for by assuming them to be stragglers from the males derived during sexual encounters. A much larger number of millipedes than those listed here were examined at the Bluff on many

FEMALES AND PREADULT MILLIPEDES.

| | *Neomegistus.* | *Paramegistus.* |
|---|---|---|
| Females 1 | .. | 2 |
| 2 | .. | .. |
| 3 | .. | .. |
| 4 | .. | .. |
| 5 | .. | .. |
| 6 | .. | .. |
| 7 | .. | 2 |
| 8 | .. | 5 |
| 9 | .. | 1 |
| 10 | .. | 1 |
| 11 | .. | .. |
| 12 | .. | 1 |
| 13 | .. | 2 |
| 14 | .. | .. |
| 15 | .. | .. |
| 16 | .. | .. |
| 17 | .. | .. |
| 18 | .. | .. |
| Preadult 1 | .. | 5 |
| 2 | .. | .. |
| 3 | .. | 3 |
| 4 | .. | .. |
| 5 | .. | .. |
| 6 | .. | .. |
| 7 | .. | 1 |
| 8 | .. | 1 |
| 9 | .. | 4 |
| Total | .. | 28 |

AVERAGE NUMBER OF MITES PER MILLIPEDE.

| | Total *Neomegistus.* | Total *Paramegistus.* | Average of *Neomegistus.* | Average of *Paramegistus.* | Average of *All Mites.* |
|---|---|---|---|---|---|
| 27 males . | 91 | 103 | 3·4 | 3·8 | 7·2 |
| 18 females . | 0 | 14 | .. | ·78 | ·78 |
| 9 preadult | 0 | 14 | .. | 1·6 | 1·6 |

different occasions without making counts of their mite parasites. In no cases did the females ever carry *Neomegistus*, though a number had specimens of *Paramegistus* upon them. Even females taken *in copula* failed to show any specimens of *Neomegistus*.

### The Feeding of Neomegistus and Paramegistus.

While it is difficult to give a reason for the curious situation revealed in the last paragraph without further investigation, it has occurred to me that the almost entire absence of the two mites from the female millipedes might be explained by their feeding habits, assuming that the few specimens of mites found on the females passed over to them from males during copulation.

Trägårdh, in his second paper on these mites, advanced the rather curious theory that they fed upon the secretions of the odoriferous glands of the host millipede; he based this belief partly upon the presence of a large brush-like appendage attached to the mandibles of *Neomegistus*, which would well serve the purpose of sweeping and sucking up liquid food. The same type of appendage is found in *Paramegistus*, though developed to a less extent.

It would seem probable that during the long period from October to March the mites must partake of some sort of food, and that this food is taken in liquid form. I cannot agree, however, that the odoriferous secretions of any millipede, being excreted for defensive purposes and therefore a substance repugnant to most creatures, would provide a very nutritious food material. Pawlowsky (4) and Verhoeff (5) have given short accounts of what little is known about the composition of the defensive secretions of millipedes. The various workers quoted by these authors have shown that the secretions of many Diplopoda contain iodine and some hydrocyanic acid as well; injections of the substance into small mammals have a definitely toxic effect. All authors agree, however, in stressing the irritant and repellant nature of the secretion.

A further objection to this supposition lies in the fact that it is difficult to make *Doratogonus setosus* secrete at all, and it will tolerate a great deal of handling and actual pressure before drops of the secretion begin to appear at the gland openings. The reverse is the case in all species of *Chersastus*, where quite gentle handling of a specimen provokes a strong secretion of yellow-brown liquid which leaves a dark purple or brown stain on the fingers. According to my observations the larger South African millipedes, which belong to a different suborder (Spirostreptoidea) from that which includes *Chersastus* (Spiroboloidea), secrete very little, while smaller millipedes like *Julomorpha* and *Chersastus* secrete copiously when handled.

It is therefore more probable that the secretions of the lateral body glands (Wehrdrüsen) of millipedes can be excluded as the source of the food supply for the mites.

It seems to me more probable that the mites feed on the seminal fluid

of the male millipedes, a theory which may at first sight appear as extraordinary as that advanced by Trägårdh. This, however, would account for the constant presence of the mites on the males of *Doratogonus* during the summer months, *i.e.* the mating season of the millipede, and its absence from the females. I was often able to find the sexes of the millipedes in copula, which could also be indirectly induced by merely bringing millipedes of the two sexes into contact with each other. I observed the act of copulation on numerous occasions, and will not go into greater details of the process than by merely observing that it follows the same general lines described by Gerhardt (6) in his interesting description of the sexual act in *Graphidostreptus gigas* (Peters), a large Spirostreptid from East Africa. A fact which he does not mention, however, and which I noted on every occasion, was that after the distended gonopods had been withdrawn from the vulva of the female they were almost entirely covered with a milky liquid mass, the excess seminal fluid. A large amount of this fluid adhered to the neighbouring legs and sternites of the male, while some could also be seen on the area surrounding the vulva of the female. This is, undoubtedly, seminal fluid, as it can be taken from the millipede with a capillary tube and examined to show the characteristic shape of the non-motile sperm bodies. These resemble the spermatozoa of the allied genus *Poratophilus* which have been figured by Warren (7, p. 388, fig. 7c, *c*), but are more definitely triangular in shape than those of *Poratophilus* when viewed from the front. It is this sperm therefore that, in my opinion, provides the liquid food of the mites during the summer months.

I was, unfortunately, never able to see the mites in the act of feeding, though I repeatedly observed millipedes in the act of copulating and watched the behaviour of the male subsequently with the aid of field-glasses. Immediately after copulation the male carefully cleans its gonopods and the walking legs near them with its mouth, removing most of the traces of sperm in a few minutes. To do this the gonopods may be extruded several times to allow the millipede to reach all the complicated parts with its mouth.' During this operation a number of *Neomegistus* showed a definite interest in what was being done, standing on the collum and at the sides of the seventh segment, and passing repeatedly from one side to the other over the back of the host. One mite came very close during this process by approaching over the frons, eventually getting as far as the labrum; none of the mites, however, remained quiet for very long, advancing as near to the gonopods as possible and then retreating quickly at the least sign of danger. The chief danger, or reason for their retreat, seemed to be the continual movement of the legs and head of the millipede, which appeared as if it might sweep them off. They carefully avoided all contact with the continually moving legs of the host.

The mites may thus have to wait until the male millipede has completed its toilet before they are able to take what is left of the sperm. It is improbable that the cleaning process is so thorough that some sperm is not left in the crevices between the legs and sternum which would be sufficient to provide a meal for these small parasites. As soon as the attention of the host was engaged with something else they would be quite free to complete the scavenging process, an arrangement which would doubtless benefit both parties.

In general the movements of the mites are rapid and they are able, as Trägårdh has noted, to move forwards, backwards, and sideways with equal ease. I most often saw them walking sideways. They are able to move very quickly from one end of the millipede to the other along the natural groove formed just above the insertion of the legs, where they also took refuge when attempts were made to grasp them with the forceps.

They adhere firmly to the chitin of the host, being difficult to remove, but sometimes fall off when the millipede is handled. Numbers were found still attached to millipedes which had been killed in alcohol.

## Summary.

Certain observations on the biology of two Gamasid mites, *Neomegistus* and *Paramegistus*, living on a Spirostreptid millipede *Doratogonus setosus uncinatus* at Durban, are recorded. These mites are found on the male millipedes but not on the females, and only during the summer months. Trägårdh, when describing the biology of the mites in 1907 put forward the suggestion that, judging from the structure of the mouth-parts, they fed upon a liquid substance, and he thought this substance to be the defensive secretions of the odoriferous glands of the millipede. The writer, as an alternative theory, suggests that the liquid food is the seminal fluid of the millipede, in view of the fact that the mites occur almost entirely on male millipedes during the mating season of the latter.

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# THE STELLENBOSCH INDUSTRY IN THE WAGENMAKERS VALLEI.

By F. Malan.

(Communicated by A. J. H. Goodwin.)

(With Plates IX–XI and twenty-nine Text-figures.)

(Read May 17, 1939.)

## Introduction.

In his introduction to "The Stone Ages of South Africa," Annals of the S.A. Museum, vol. viii, 1912, the late Dr. Péringuey wrote the following words: "This paper is not an attempt to solve problems of great consequence for that section of the science of Anthropology dealing with the stone implements, the artefacts of man who had ceased to be anthropomorphous ape. It is a recapitulation, it can hardly be called a narrative of information obtained in South Africa, classified wrongly or rightly according to the tenets obtaining now."

It would be difficult to find more apt words with which to introduce this paper. The material described below was collected and studied by an amateur interested in the stone implements, and residing in a locality rich in relics, of the Stone Age. It is the fruit of his leisure hours. He has no theory to propound, no solution to offer to the many problems with which the subject is beset. To describe as clearly and concisely as possible the material and data he has collected is his sole aim; his sole wish is, that it may be of use to those whose difficult task it is to write the Prehistory of our country. Gladly would he have left it in the hands of abler men, but those he approached were most emphatic in their assertion that it could best be performed by the person who had done the fieldwork, and it is greatly due to the encouragement and help received from them that this work was undertaken.

## The Sites.

For the purpose of this paper implements from an area roughly 9 square miles in extent were selected. Being within easy reach of the writer's residence, this area could be thoroughly studied. It is an extremely rich archaeological field, and fully representative of the Stellenbosch Industry

of the Southern Cape. It lies immediately to the north of the Wellington township, and forms part of what is called on old maps and documents the Wagenmakers Vallei. On the east lies Groenberg; to the west runs the main road from Wellington Railway Station to Hermon. Three low ranges of hills—the foothills of Groenberg—cross this area from east to west almost parallel to each other, forming two shallow valleys. The southern range leaves the slopes of Groenberg on the farm Uitkyk, and, after forming the knoll to the north-east of Wellington, known locally as Prospect Hill, slopes gently in the direction of the railway station. The central and northern ranges gradually diminish in height after the mountain slopes are left behind, and are almost level with the valley floors where they are crossed by the railway line, 2 miles to the west of Groenberg, but rise again to form two isolated hills lying between the railway and the Hermon Road. The Berg River flows about half a mile to the west of this road, and the whole area described lies in its drainage basin. The ground is intensely cultivated and utilised for the growing of fruit-trees and vines.

## The Gravel Deposits.

The surface deposits on these hills vary according to whether they are derived from the weathering of the granite rocks, or of the rocks and shales of the Malmesbury Series. Near Groenberg the surface soil is a light sand, the residual quartz grains of the decomposed granite forming its chief constituent. Below this superficial layer is a bed of sandy clay, blue-grey or yellow to brown in colour, depending upon the degree of oxidation of its ferrous compounds. About a mile to the west of the mountain, the surface soil changes to a reddish-brown clay containing numerous angular quartz fragments, overlying the clay slates of the Malmesbury Beds, or separated from them by a few feet of sandy clay. In some places a layer of water-worn quartzite gravel occurs at varying depths below the surface. In the decomposed granite deposits it lies at the base of the overlying sandy soils, resting on the more consolidated sandy clay deposit. In the soils derived from the Malmesbury Beds it also appears at the base of the surface soil, and usually includes lumps of angular quartz. These gravels are here almost without exception implementiferous, sometimes appearing as a layer of implements, flakes and cores, with very few unworked pebbles. The pebbles incorporated in these gravels are mostly small, seldom exceeding 10 inches across their main axes, though large boulders do occur. This fact is of importance, and it will again be referred to later. When a field is prepared for the planting of fruit-trees or vines, it is ploughed to a depth of 20 inches or more. This is sufficiently deep to bring the implements to the surface in some areas only. These exposures

are named "sites" in this paper, and it will be clear that the size of each is dependent on the thickness of the covering soil, and the depth of ploughing.

### The Term "Stellenbosch Industry."

It is as well at the outset to explain the use made in this paper of the term "Stellenbosch Industry." The writer is not unaware of, or even unsympathetic to the subdivisions recognised elsewhere. From the descriptions and sketches which follow, the reader will note the variety of methods employed for the manufacture of the various types, as well as the remarkable morphological differences encountered. All this seems to call for a division of the Industry into phases or periods. It is, however, obvious that if such phases or periods can be maintained they must rest on data collected on or near the field investigated. Let us briefly examine the data so far collected here under the following heads: (*a*) Stratigraphy, (*b*) Association, (*c*) State of Preservation, and (*d*) Typology.

(*a*) *Stratigraphy:* As described above, the implements usually occur in a single layer of water-worn gravel at the base of the surface soils. Two exceptions to this have been observed. In the first, some of the implements and pebbles have sunk, most probably by gravity, into the underlying clay. In the second, a donga in a valley reveals a layer of implements and pebbles under from 6 to 9 feet of alluvial clay. In both instances, the ferrous compounds have been dissolved from the outer crust of the quartzite and the implements are of a dirty white colour. Pebble types predominate in the second instance, but this is probably due to mechanical sorting by the transporting stream. In both instances mentioned there appears to be no geological evidence for assigning the types found below to an earlier stage of the Industry. Diligent search has so far failed to discover simple stratigraphy in this area.

(*b*) *Association:* Most of the implements were collected on the exposures or sites described above, where they appear strewn on the surface in vineyards or orchards. As only a single bed of implementiferous gravel occurs, often exposed in the sides of drainage furrows in the immediate vicinity of the site, it is assumed that all the material found on the surface comes from the pebble-bed. The various types are found in close association, and no variation is noticeable in the different site assemblages.

(*c*) *State of Preservation:* The implements can be divided into five groups by using their state of preservation as a means of classifying them. (i) For the first the term "mintstate" can be borrowed from the numismatists; in other words, the state in which they were manufactured, showing no sign of wear or rolling, Plates X and XI. (ii) Rolled or water-worn (Plate IX, No. 1). (iii) Rolled and subsequently retrimmed (Plate IX, No. 2). (iv) With a growth of laterite attached to the implement (Plate IX, No. 3). (v) A state in which the quartzite had been changed to a lump of ferruginous matter, probably by the action of colloidal iron in the soil-water (Plate IX, No. 4). The large majority of implements belong to the first group. Specimens belonging to Groups (ii) and (iii) are comparatively

rare, and, to judge by those so far recovered, all types appear to have been indiscriminately affected. Implements that have suffered chemical change (Groups (iv) and (v)) offer little help, because all the specimens on certain areas have been equally affected by the particular conditions prevailing. Group (v), for instance, appears in depressions where the seepage is excessive in winter, or where the soil tends to become water-logged. This method of subdivision has so far yielded negative results only.

(*d*) *Typology:* The number of types, and the various methods of manufacture, have already been referred to. The Industry may be divided typologically into at least four phases as follows: *Phase* 1: Implements are manufactured by detaching a minimum of flakes from a pebble, or rarely, from a flake previously detached from a boulder. Crude, asymmetrical with very sinuous edges and no secondary trimming. *Phase* 2: Implements become more symmetrical; an effort is made to straighten the edges by removing the ridges left between the primary flake scars. The flake is used to a greater extent, and often shows a very wide angle between the striking platform and flake surface. *Phase* 3: The implements are beautifully symmetrical, evenly flaked over both faces of the bouchers; the edges are fine and straight, and the cross-section almost perfectly lenticular. *Phase* 4: In the remaining phase there is a decline both in the number and size of the larger types, and an ascendancy of the blade types, particularly the triangular point with convergent flaking and faceted butt.

These, in very brief outline, are the subdivisions which may be made on typological considerations. It must immediately be admitted, however, that they are not satisfactory. They tend to give the impression of separateness or disconnectedness to the Industry, with the result that many of the specimens encountered will not readily fit into any of the phases enumerated above, but will, so to say, fall between them. The state of preservation of some of the implements indicates that the Industry was practised for some considerable time, a view supported by the development noticeable in the technique. Whether such development was steadily progressive, or whether there were periods of stagnation or even retrogression are questions which can only be answered when clear stratigraphical evidence is forthcoming. A geological survey for these parts is overdue.

It is with some diffidence that the writer proceeds to give the impression he has gained as the result of a close study of the Industry over a number of years. Its chief characteristic is its remarkable continuity. Beginning with a few simple types, the implements increase in number and complexity, telling the story of steady, unbroken human development over a considerable period of time. There are no gaps; neither is there much cause for assuming an influx of inhabitants from elsewhere bearing a new culture, or practising a new technique. The beginnings of each new type are already apparent in what has preceded it. It is hoped that the following illustration will help to clear the picture. Let us assume that eight types constitute

the full range of implements in the Industry. Beginning with the simple forms, we will name these Types *a*, *b*, *c*, *d*, etc. If the Industry is divided into four phases as above, and we assume further that each phase shows two new types, the first would then be Phase *ab*. But Phase 2 could not be written as Phase *cd*, but as Phase *abcd*, because each new Phase is an addition to, as well as a growth out of what has gone before. Old types are not necessarily discarded, but new ones are added with which to perform the new tasks consequent to the ever-increasing complexity of human needs. As development proceeds, something new makes its appearance, something for which a symbol outside and above the eight letters agreed upon must be found. This is a tendency to achieve symmetry, if not beauty, in some types, which cannot have as sole cause the giving of greater handiness or usefulness to the artefacts. This appreciation of symmetry, which no doubt indicates some awakening of the aesthetic powers, will be denoted by the letter $x$. With this addition, the four Phases can now be more accurately expressed as Phase $ab-x$, Phase $abcd+x$, and so on. A true and realistic picture is, however, only obtained when the final Phase is reached, because it is Phase $abcdefgh+x$ which occurs on these sites, and to which the term "Stellenbosch Industry" is applied in this paper.

### Description of Types.

To give a clear representation of the Stellenbosch Industry is by no means an easy task. The casual observer may see no more in it than a few forms of bouchers and cleavers, mostly left unfinished, together with a heterogeneous collection of discoidal artefacts, cores and flakes. A more intimate study, however, gives a very different view. The types both of bouchers and cleavers multiply. What was regarded as unfinished, because it was wrongly compared with the beautiful symmetry and retouch desired and achieved in other types, becomes design and perfection. There is sometimes even a combination of two forms in a single implement, a veritable "two-tools-in-one," revealing a totally unexpected ingenuity. This paper can give no more than a bare outline of this variability, this remarkable specialisation. The reader wishing to obtain more detail must study the Industry in the field. No matter how detailed the description or clear the sketch, the armchair perspective must necessarily be somewhat distorted.

### Size of Implements.

The relative size of the various types can be easily gauged from the sketches, as these have all been drawn to the same scale. As far as possible only specimens of normal size have been selected for illustration. The two figures on text-fig. 1 show the largest and smallest of the almond-shaped

bouchers found on these sites. See also Plate X. The small specimens are more commonly met with. Many of the types show these giants and pygmies: for instance, the largest cleaver recovered measures 252 × 128 × 62 mm., the smallest 64 × 45 × 20 mm. (Plate X, No. 5). It was mentioned above that the pebbles incorporated in these gravels are seldom above 10 inches across their main axes. As the gravels were the source of supply of raw material, it is not surprising to find that the implements are generally small in comparison with those from neighbouring districts. To obtain an average for the size of the bouchers occurring here, two hundred and fifty complete specimens were measured. The following table shows the details:—

*Length of Main Axis.*

| Below 100 mm. | 101 to 150 mm. | 151 to 200 mm. | 201 to 250 mm. | Above 250 mm. |
|---|---|---|---|---|
| 16 | 101 | 98 | 25 | 10 |

| | |
|---|---|
| Smallest specimen, | 87 × 48 × 28 mm. |
| Largest specimen, | 290 × 131 × 73 mm. |
| Average size, | 153 × 91 × 49 mm. |

A boucher of approximately average size is illustrated on Plate X, No. 2. It measures 157 × 84 × 47 mm. It will be noticed that 86 per cent. of the bouchers have a main axis of less than 250 mm., or nearly 10 inches, and the average length is only in the neighbourhood of 6 inches. The size of the completed implement is, of course, governed by the size of the material available for its manufacture. But a second, and almost equally important factor, is the use made of such material—in other words, the method of manufacture employed. The following methods appear to have been used on these sites: (i) the paring down of a water-worn pebble to the required shape; (ii) (*a*) the splitting of a suitable pebble, or (*b*) the detaching of a flake from a pebble, and the use of such a flake as basis for the manufacture of the required implement; (iii) the detaching of a large flake from a boulder, and proceeding as in (ii). Owing to the scarcity of large boulders, the last method was not often employed. The second method generally produces the smallest implements, and this was the one most extensively used on these sites.

### Bouchers from Pebbles.

A study of the various types of implements in the Stellenbosch Industry reveals at least two lines of development. The first towards an ever greater perfection of the technique, the second towards a simplification of the technique by a more careful selection of material, thus reducing the

labour necessary for the perfection of the required form. Nowhere is this more clearly seen than in the manufacture of the boucher from the pebble. By the careful selection of suitable pebble shapes, flaking was reduced to a minimum. This seems to have escaped the notice of some investigators, with the result that many types have been passed over as unfinished. The fact that these implements occur again and again, in the same state of perfection, or imperfection, seems to prove that they are completed specimens, and the selection of the pebble shape to conform as far as possible to the shape of the required implement reveals a truly remarkable ingeniousness. On text-figs. 2 and 3 there are illustrated a few of the methods employed for the manufacture of the boucher from the pebble. Text-fig. 2, fig. 1, shows three views of a boucher made by sharpening one end of an ovate pebble. In some cases the detaching of three or four flakes sufficed to achieve this purpose; in others, the primary work was carefully retouched, and a fine, even point resulted (Plate XI, fig. 4). Sometimes the flaking was carried round the butt, but seldom was the entire outer crust, or cortex, of the pebble removed. For the manufacture of this type almost any ovate pebble could be used, but text-fig. 2, fig. 2, shows a pear-shaped boucher, the manufacture of which depended on the maker finding a pebble of suitable shape. Only about two-thirds of one face had to be artificially shaped by flaking. The removal of a few flakes on the opposite face brought the sharp edges up the perimeter towards the butt. The finished artefact is both simple and neat. Text-fig. 3, fig. 1, is another example of the selection of material with the object of reducing labour. In this instance the whole of one face is left untrimmed, only a part of the opposite face being flaked to give the required shape. In some specimens the whole of one face was trimmed, but more often the flaking of half to two-thirds of one face, from the point upwards, sufficed to complete the implement. Text-fig. 3, fig. 2, illustrates a method of treating a pebble with two flat surfaces opposed to each other, so as to achieve an almond-shaped boucher. These implements seldom show the fine workmanship of the last two types described. They are usually heavy implements roughly hacked out of the pebble.

These are some of the methods employed for the manufacture of the boucher from the pebble. It will perhaps be questioned whether the implement-makers deliberately chose their material, whether the shape of the implement was not rather forced on them by the shape of the material to hand? In reply, it can only be stated that when, not one or two, but a whole series of these implements, from widely scattered sites, are seen together and handled, the remarkable similarity of shape and method of flaking point unmistakably to their having been conceived and executed according to plan. There is nothing fortuitous in their appearance; on

the contrary, they reveal the sure touch of the workman fully conscious of his skill. It appears rather to be another manifestation of that need to invent which produced the flake implement, and later, the prepared core.

### Bouchers from Flakes.

Before proceeding with the description of some of the methods employed for the manufacture of the boucher from the flake, it must first of all be understood that this method is an integral part of the Stellenbosch Industry. The development of the flake technique proceeded *pari passu* with the pebble or core technique, and cannot be separated from it. On these sites, the most prevalent method for obtaining the flake to be utilised was to split a pebble either by a blow on the end or on the side. By selecting a pebble of suitable shape and applying the first method, it was possible to reduce work to an absolute minimum, and obtain a complete implement by a single blow. Such pieces (text-fig. 4, fig. 1) are numerous on these sites, and are almost invariably end-flakes. Sometimes a too prominent bulb of percussion is trimmed down. Occasionally, as illustrated on text-fig. 4, fig. 2, when two convex faces were required, the whole of the flake surface was retrimmed, making it impossible to tell whether the work was started on an end- or side-flake. Text-fig. 5 illustrates two end-flake bouchers with the pebble surface trimmed to the required shape; the former is of frequent occurrence. When a flake was obtained by the second method, that is, when the pebble was struck a lateral blow, it was almost invariably found necessary to remove the bulb of percussion by further flaking. Two such side-flake implements are illustrated on text-fig. 6. Note the method of trimming (fig. 1), by removing a few flakes near the point on the one side and near the butt on the opposite side the implement is perfected with the least amount of trimming. In some specimens flaking is carried round the perimeter, leaving a patch of cortex in the centre of one face. More often flaking started near the point and was carried up towards the butt as far as necessary. The third method of obtaining a flake was to detach it from a boulder by using a corner as striking platform, or by preparing a platform by first removing a flake so as to form an acute angle with the face to be removed. Such a large flake or primary broadflake, as it has aptly been named, was then trimmed to the required shape. A second blow, lower than the first, could sometimes be struck, producing a secondary broadflake. Text-fig. 7 shows two bouchers manufactured from broadflakes, fig. 1 from a primary, and fig. 2 from a secondary broadflake. Note the absence of the bulbs of percussion, so prominent in the other figures illustrated, and the uniform thickness of these implements, shown in the side views. As stated above, this method

was not often used here, owing to the small size of the raw material available. It was, however, extensively practised on sites where large boulders were plentiful.

As the natural or most likely shape of the boucher, derived from the pebble, is the pear shape, so the natural shape of that derived from the flake is the almond, or the oval. Implements of the last type are comparatively scarce on these sites. Most of the specimens occurring here are so finely flaked over both faces (Plate XI, No. 1), that it is impossible to say by which of the three methods described above they were manufactured. Those showing part of the original flake surface appear mostly to have been made on side-flakes.

The almond-shaped bouchers often have a flat, eye-shaped patch at the back or on the side of the butt (Plate XI, Nos. 2 and 3). It is less often found in the oval, and rarely on the pear shapes. Occasionally implements occur with two such patches, one on each side of the butt (text-fig. 8, fig. 1). The specimen illustrated shows a patch of crust on one side, and a plane flake surface on the other. A few specimens of the almond shape have been found that show a lengthening of the butt to form a kind of hand-grip. Another method of modifying the butt by detaching two large flakes from one side, thinning it, and forming a kind of tang is illustrated on text-fig. 8, fig. 2.

### Modified Forms.

Innumerable modifications of the forms described above are met with. While many of these were no doubt required for some special purpose, a large number probably represent the effort of the amateur tool-maker. A form often seen here is illustrated in text-fig. 9, fig. 1. These implements are usually asymmetrical, bent over to one side, but symmetrical diamond-shaped specimens also occur. The flaking on this type is usually large and bold, and the edges are very sinuous. Text-fig. 9, fig. 2, illustrates a scraper type of boucher. A pebble with one plane face seems to have been favoured for their manufacture, but a few specimens show a flake surface on the ventral face. In some a rounded edge replaces the sharp triangular point. The various forms of bouchers, some of which are short and stocky, while others are long and narrow, suggest the operations of boring, cutting, scraping and digging.

### The Chisel-edged Implement.

Specimens of this type are numerous on these sites. The methods of manufacturing them are similar to those described for the bouchers. They are, in fact, merely bouchers with flat chisel-edged points. The majority are pear-shaped and manufactured from pebbles. Text-fig. 10, fig. 1,

shows the method of treating a pebble to achieve this form. Fig. 2 on the same text-figure illustrates a typical specimen, completely flaked over both faces. Occasionally a split pebble was used for the manufacture of the implement. Text-fig. 11, fig. 1, shows a specimen made on a part of a pebble split by a blow at the end, and fig. 2 another made on a pebble split by a lateral blow. Compare the latter with the bouchers illustrated on text-fig. 6 and note the similar method of trimming the flake surface. The width of the cutting edge ranges from about 10 mm. to over 70 mm. in some specimens, the latter approaching the cleaver form. Some have the cutting edge at right angles to the main axis, others have an oblique edge. Large, heavy specimens are often met with, but very small specimens are rare.

### The Cleaver.

The cleaver, or biseau, types are very well represented here. Numerically they come second to the bouchers only. The writer once counted twelve specimens on an area less than 20 feet square. Morphologically, they can be divided roughly into four classes; these will be described separately. Class 1 is the form most commonly met with, with sides more or less parallel, the butt square or rounded, the cutting edge curved or straight and at right angles to or oblique to the main axis. Class 2 is the triangular or tranchet form, with the same modifications to butt and cutting edge as Class 1. Class 3 can best be described as the tongue-shaped type, and Class 4 is the crescent-backed axe, rare on these sites. All these types have one feature in common: they all have a sharp cutting edge, formed by the junction of two cleavage faces, or a cleavage face, with a pebble surface.

#### *Class* 1.

A typical example of this type is shown on text-fig. 12, fig. 1, and is of more or less average size. Smaller specimens are numerous and, to save space, several have been chosen for the illustrations. The cleaver is essentially a flake implement, though core implements are not entirely absent. The method for obtaining a cleaver from a pebble was to detach two large flakes, one from each side, so that the central portion formed a wedge. This wedge was then further trimmed by flaking first from one of these large flake scars across the thickness of the stone. The stone was then turned over, and flaking done in an opposite direction, using the second flake scar as platform. The completed implement usually has a parallelogram cross-section, is longer and thicker than the flake implements, and somewhat resembles the chisel-edged type. The large majority of cleavers are made on side-flakes. As in the manufacture of the boucher, by a careful selection of pebbles of suitable shape, it was found possible

to reduce the flaking to a minimum. Implements completed by a single blow are not rare. Sometimes only one edge was trimmed (text-fig. 13, fig. 1); more often both edges were trimmed, either from opposite faces, as described above, giving a parallelogram cross-section (text-fig. 13, fig. 3), or from one face only, giving a trapeziform cross-section (text-fig. 13, fig. 2). Where the bulb of percussion was too prominent, it was removed by further flaking (text-fig. 12, fig. 2). In some specimens the edge is so round that the form approaches that of the oval boucher (text-fig. 14, fig. 1). A few specimens have notches cut in the sides near the cutting-edge, the flaking for these being done from opposite faces. Bent specimens also occur, having one side slightly concave, the other convex (text-fig. 14, fig. 2).

*Class* 2.

Though not so numerous as the Class 1 type, the triangular cleaver is nevertheless well represented. The form most commonly met with is illustrated on text-fig. 15, fig. 1. The methods of manufacture are the same as described above for Class 1, with this exception that a larger percentage of the triangular form are made on end-flakes. Core implements are extremely rare, but thick flakes or lumps were occasionally used; such an implement is illustrated on text-fig. 15, fig. 2. Two examples on secondary flakes are shown on text-fig. 16, fig. 1, with trapeziform cross-section, and fig. 2 with parallelogram cross-section. The pointed butt of the second specimen is seldom seen here. In some specimens of this class the sides are slightly concave, especially near the cutting-edge, giving the implement a bell-shaped outline.

*Class* 3.

The chief feature of this form is its semi-elliptic or tongue-shaped cutting edge; in other respects it resembles Class 2. In some specimens the edge is almost semicircular, notably in the shortened form (text-fig. 16, fig. 3). The type usually met with is shown on text-fig. 18, fig. 1. The tanged variety (two typical specimens of which are illustrated on text-fig. 17, figs. 1 and 2) is rarely found.

*Class* 4.

The scarcity of large boulders in the gravels probably accounts for the small number of the type illustrated on text-fig. 19 occurring here. They are essentially broadflake implements. Most specimens are large and heavy, the back boldly trimmed in the characteristic manner shown by the figure on the right. Flaking is done from opposite sides and opposite ends of the back, and the intersection of the two opposed flaked

surfaces forms a sharp edge or ridge running obliquely across it. This peculiar method of treating the back is also applied to the manufacture of some of the cutters to be described below.

Though the large majority of cleavers can, without much difficulty, be assigned to one of the four classes, specimens are occasionally found in which the features peculiar to two classes are combined. Still other types, best described as composite implements, appear to lie halfway between the cleaver form and that of some other implement. The close similarity of the form illustrated on text-fig. 18, fig. 2, with that of the cutters on text-fig. 22 is unmistakable. Even more remarkable are the cleaver-boucher forms shown on text-fig. 20. It appears that what was aimed at was an implement that could serve either as a boucher or a cleaver. In fig. 1, as in some cleavers, steep flaking across the thickness of the flake is employed to produce the required shape. In fig. 2 the same form is achieved by step-flaking. These implements seem to offer a clue to the use of the asymmetrical boucher forms.

## Cutting Implements.

Almost any flake detached from a quartzite pebble has at least one edge eminently suitable for use as a knife or cutter. It is not surprising therefore to find several types of cutting implements in the assemblage. As in the cleaver, the cutting edge is simply formed by the junction of two flake surfaces, or a flake surface and pebble surface. Secondary flaking is almost invariably confined to shaping the back or butt. While some types are easily recognised, others appear to be by-products, in other words, flakes derived from the manufacture of the larger implements. There can be little doubt that some, especially the smaller types, had such an origin, but the frequency with which some forms are met seems to offer enough reason for assuming that they were desired, and specially manufactured. The examples illustrated occur frequently, and fit the hand easily when held in the position for cutting. A biconvex flake, showing a positive bulb of percussion on both faces, often formed the basis for the manufacture of the various cutters. To obtain this, a thick flake or lump was detached from a pebble showing a positive bulb of percussion on the cleavage surface. Using this as a core, a flake was again struck from it by a blow opposite to the first, or shifted to one side of it. The first method produced a keen, straight edge, the second usually gave the edge the well-known S-twist. The illustrations show the back and two faces of the implements.

## The Half-Crescent Cutters.

The type of cutting implement most commonly met with may be described as the semi-crescent or half-crescent cutter, because its shape is

roughly that of a crescent cut across its minor axis. The back is usually more or less straight, the cutting edge curving up to meet it at the point. Text-fig. 21 illustrates two typical examples, fig. 1 on a primary, and fig. 2 on a secondary flake. A short form also occurs, and is shown on text-fig. 22. A biconvex flake, obtained by the method described above was used for the manufacture of the specimen illustrated in fig. 2. Specimens are occasionally found pointed at both ends, and almost exactly the shape of the harness-maker's half-moon knife. They are usually made on biconvex flakes, and the back trimmed in the characteristic manner shown on text-fig 19, leaving a ridge running obliquely across it. The typical form was sometimes obtained by a single blow.

### Semicircular and Crescent Cutters.

Two types of small cutters, the semicircular and crescent, have been recognised. The former is usually made on a biconvex flake, and the back is trimmed so as to leave the ridge across it (text-fig. 23, fig. 1). The type illustrated on text-fig. 23, fig. 2, is more numerous than the semicircular form, and often occurs with a straight cutting-edge, the true crescent form. Both these cutters belong to the small flake type of implement, and may be what has been called by-products, only one large specimen of the first form has so far been recovered here. They are better adapted for cutting than the blades. They fit the hand perfectly and more pressure can be applied to them without fear of breaking them.

### Knife Blades.

These are mainly of two kinds, a long slender form, somewhat resembling the blade of the ordinary clasp-knife, and a short thick form. Complete specimens of the former are rarely found, though numerous fragments occur. In some specimens (text-fig. 23, fig. 3) the back is untrimmed, while in others (fig. 4) on the same plate, the whole of the back is blunted by flaking across it. Trimming for the latter probably occurred on the core before the blade was detached, as the slender quartzite blade could hardly have withstood the trimming blows without snapping. The short forms (text-fig. 23, figs. 5 and 6) are more numerous, especially with untrimmed backs, probably because they were easier to manufacture, or obtained as by-products.

### Triangular Points.

Numerous large thick triangular points, distinct from those with faceted butts, occur in the Industry (text-fig. 24, fig. 1). Like the cutters and knife blades, many of these were no doubt obtained as by-products from the manufacture of the larger implements. No system or plan appears to

have been followed for their manufacture, with the result that rarely are like specimens encountered. Many show a patch of the crust of the pebble from which they were made, on one face. A few have the butt thinned by step flaking (fig. 2). Occasionally specimens are encountered with secondary trimming along the edges, but this is the exception rather than the rule. Fig. 3 illustrates a large point, retouched on both faces—a very rare occurrence. The large majority, like fig. 1, are thick and broad, and show no retouch.

### Conical Implements.

A number of these fascinating little pebble implements have been collected here. Though relatively scarce, they occur on all the sites throughout the area. Three methods for obtaining the point appear to have been followed. The first is the same as that adopted for making the boucher from the pebble. A small ovoid pebble was sharpened to a point by detaching fine flakes from two faces (text-fig. 25, fig. 1); the section near the point is lenticular or biconvex. Fig. 2 illustrates a second type in which one face is a plane surface, the opposite face almost semicircular. Some specimens of this type have the flat face of the implement wholly untrimmed pebble surface, a pebble with a flat face being selected for their manufacture. The third type has a triangular point (fig. 3, and Plate XI, No. 5) and, like the second type, a flat, untrimmed pebble surface often forms one face of the implement. All specimens are short and squat, the bodies more or less spherical, often showing a considerable proportion of cortex or pebble surface.

### Scrapers.

Although the term scraper is here used to describe all those implements common on these sites, showing a plane, or slightly concave or convex under-surface, and a curved, rather steeply flaked working edge, it does not follow that all such implements were used as scrapers. The large majority have no definite shape, and the flaking on the edge may be the result of use, rather than a shaping for use. Fig. 1 on text-fig. 26 is a typical example of such an implement. Another kind (text-fig. 26, fig. 2) exactly resembles the trimmers of the Later Stone Age Industries, and might have been used in the same way. Two forms occur frequently, however, and give reasonable grounds for assuming that they were made for use. The first (text-fig. 27, fig. 1) is usually made from a pebble about 35 mm. thick that has at least one flat face. The flaking is small and even and the working edge rounded and fairly sharp. In the second type (text-fig. 27, figs. 2 and 3) the flaking is done at a more steep angle, and in some specimens (fig. 3) flakes are struck off at regular intervals, giving the

implement a scalloped working edge. The majority of this type show a bevelled surface, natural or artificially produced by flaking, opposite the working edge, and meeting the under-surface at a wide angle. It is interesting to note that many of the cleavers and some bouchers have been so trimmed that one side is a scraper edge. See text-fig. 5, figs. 1 and 2, and text-fig. 12, fig. 1.

### Implements with Faceted Butts.

Implements with faceted butts consistently appear on sites of the Stellenbosch Industry in the Southern Cape, and a detailed description of the types occurring on the sites chosen for this study would most certainly be incomplete if it did not include them. The one feature which distinguishes this group, namely, the peculiar flaking of the butt, though rare, is nevertheless occasionally noticeable in a crude form on large flakes trimmed to the shape of the boucher. Note too the flaking on the back of the small round cutter (text-fig. 23, fig. 1). By far the most numerous in the group is the triangular point (text-fig. 28, figs. 1 and 3). The brown quartzitic sandstone, from which the other implements are made, is also used for their manufacture; specimens in silcrete are rarely found. In many specimens the width across the wings exceeds the length of the implement. Another implement with faceted butt (text-fig. 28, fig. 2) has a keen chisel edge at right angles to its main axis. The type of blade usually found is illustrated on text-fig. 28, fig. 4. Another, fig. 5, is more complex and shows a patch of cortex remaining near the tip. A single specimen has been recovered where the whole of one face is untrimmed pebble surface, the butt neatly faceted. Flakes showing faceted butts are not uncommon (text-fig. 28, fig. 6). A few show signs of having been used. Retouch on quartzite specimens is extremely rare, and usually confined to shaping the wings of some triangular points.

### Core Implements.

Apart from the cores from which useful flakes had been struck, and other formless lumps of stone, which had received their battered appearance as the result of use, there also occurs a group of what are usually termed core implements. There is a considerable variation of form and size noticeable among these. A few of the more well-defined types are illustrated on text-fig. 29. One of the forms, fig. 1, is represented by numerous specimens, both large and small, on these sites. A pebble with one flat face seems to have been favoured for its manufacture. This was so shaped by bold flaking, that, when the implement rests on its flat base, it is crowned by a sharp sinuous edge. Fig. 3 is an elongated variety of the same type, many specimens of which are pointed at both ends, and resemble

double-pointed, triangular bouchers. The polyhedral stone balls (figs. 4 and 5) are of frequent occurrence, and large specimens weighing 5 pounds and more are not rare. The double cone (fig. 6), mostly with the sinuous edge passing completely round the perimeter, is another easily recognised type, and like it but thinner is the disc form (fig. 7). Some of the faceted core implements have one or two projections (fig. 8), and where two such occur on the same implement, they are invariably opposed to each other, as in the specimen illustrated. There are numerous variations of all these forms, but rarely any signs of their having been used, unless the battered lumps of stone already referred to are unrecognisable fragments of these implements, broken as the result of the rough use to which they were put.

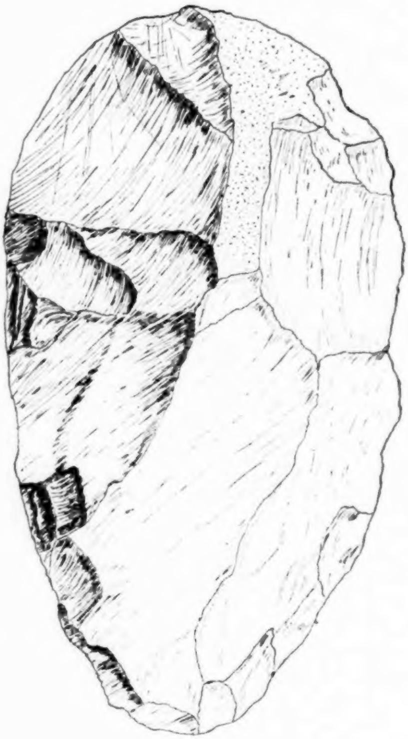
## Conclusion.

These are the main types of implements included in the Stellenbosch Industry in the Wagenmakers Vallei. The writer has refrained from adopting European terms or correlations in this paper, because he has had no first-hand acquaintance with the European field. He must likewise refrain from all discussion regarding the place of the Industry in our lithicultural period. Such discussion must be left to those whose training qualifies them to give a rational exposition. In the absence of evidence in support of a contrary view, the industry can only be regarded as a unity, and the development in technique, though by no means inconsiderable, as autochthonous.

In the Southern Mountain Area man did not have the option of using or experimenting with different materials. If his implements had to be improved, he had to improve the manipulation of his material; if a new technique produced finer implements elsewhere, he could borrow it only if it could be applied to quartzitic sandstone, the material at his disposal. It remains a high tribute to his ingenuity and skill that he reached such a state of perfection with the refractory material he was forced to use.

My thanks are due both to Mr. A. J. H. Goodwin of the Cape Town University and to Professor C. van Riet Lowe of the Bureau of Archaeology for their kind interest and helpfulness. Finally there remains the pleasant task of paying a tribute to my old friend and instructor, Dr. C. H. T. D. Heese of Riversdale. Without his encouragement and co-operation, this paper would most probably not have been written.

Groenvlei,
Wellington,
*November* 1938.



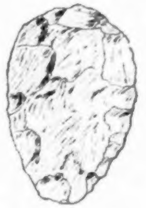


Fig.2. 84 x 56 x 25 m.m.
Weight 5 ozs.

Fig.1. 294 x 167 x 77 m.m.
Weight 8 lbs. 7 ozs.


Scale in inches and centimetres used for ALL the drawings.

TEXT-FIG. I.

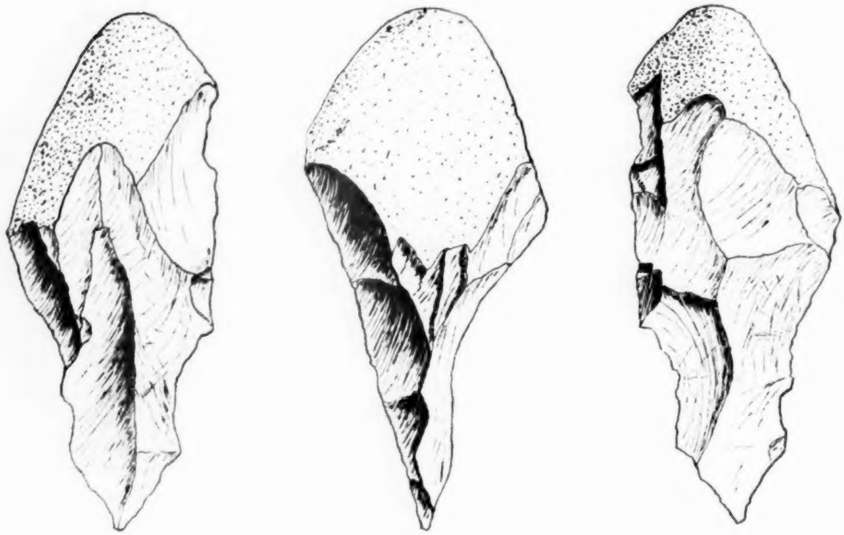


Figure 1.

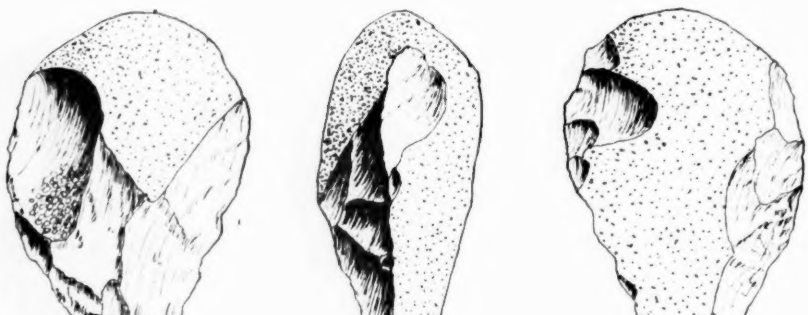
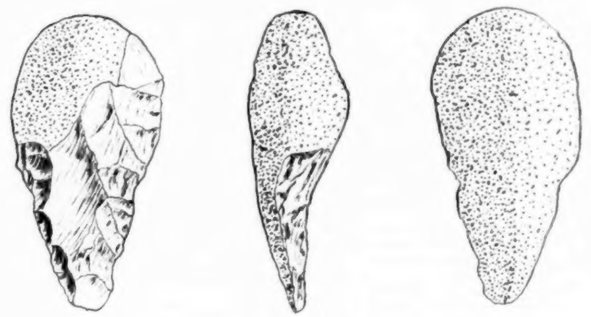


Figure 2.

TEXT-FIG. 2.



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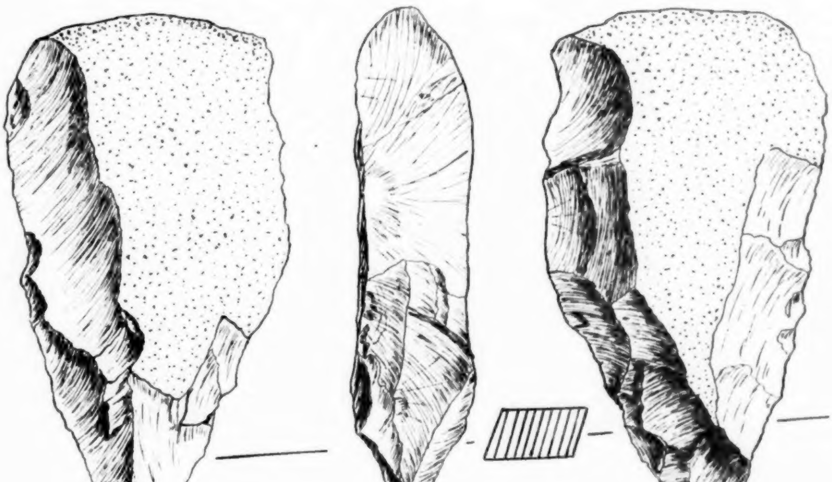


Figure 2.

TEXT-FIG. 3.

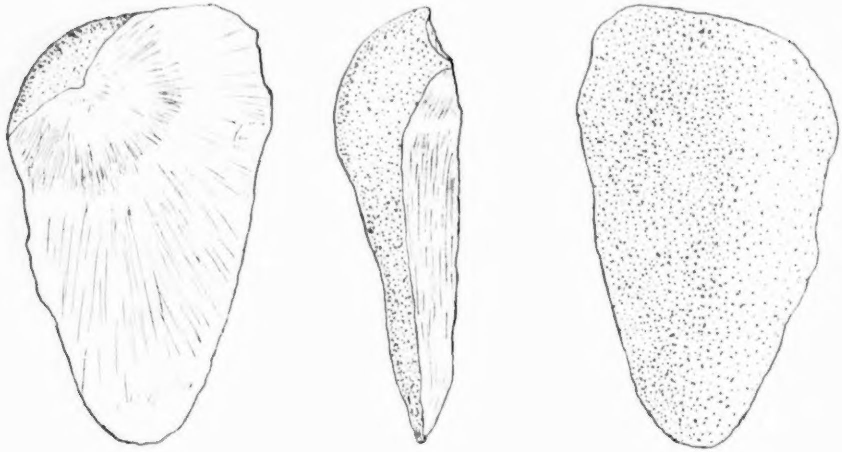


Figure 1.

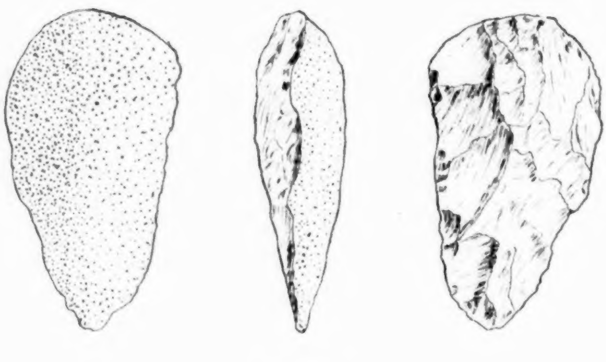


Figure 2.

TEXT-FIG. 4.

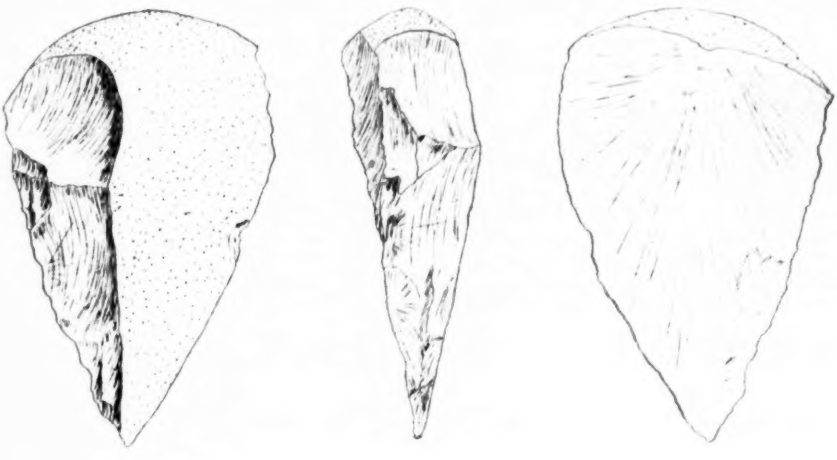


Figure 1.

Figure 2.

TEXT-FIG. 5.

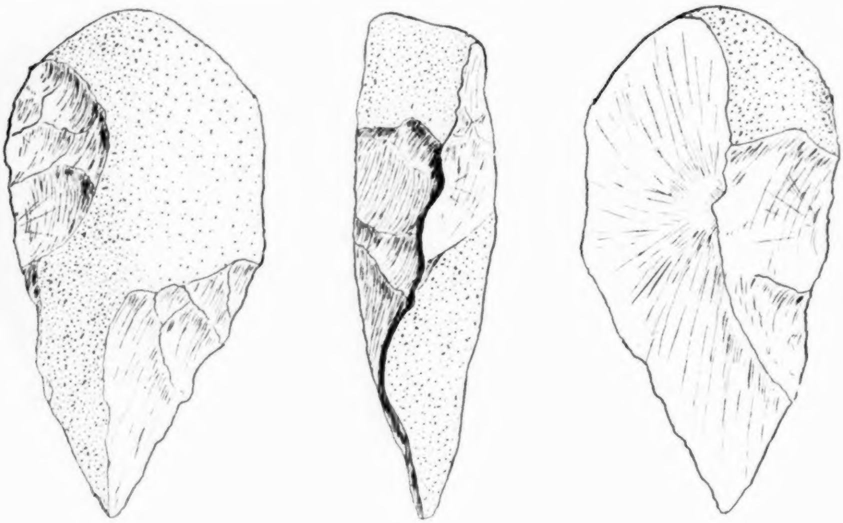


Figure 1.

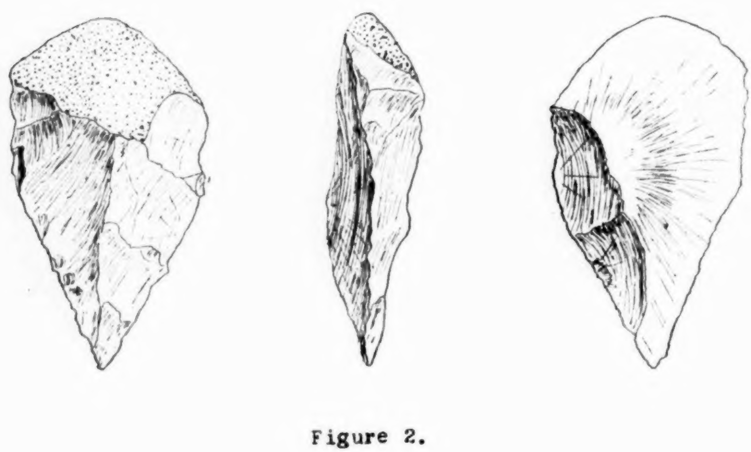
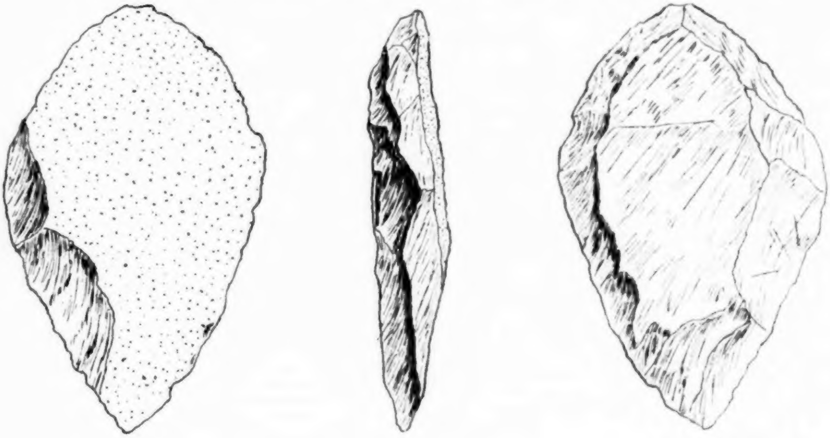


Figure 2.

TEXT-FIG. 6.



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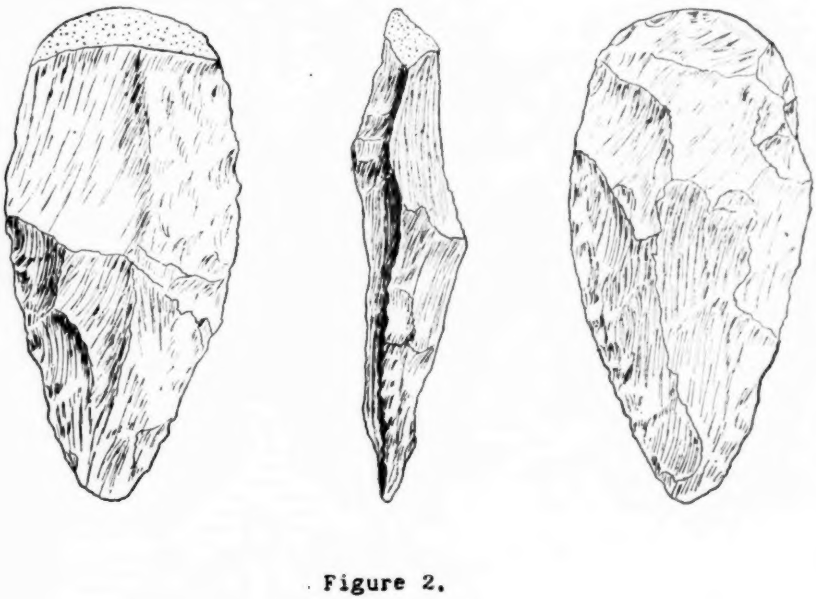


Figure 2.

TEXT-FIG. 7.

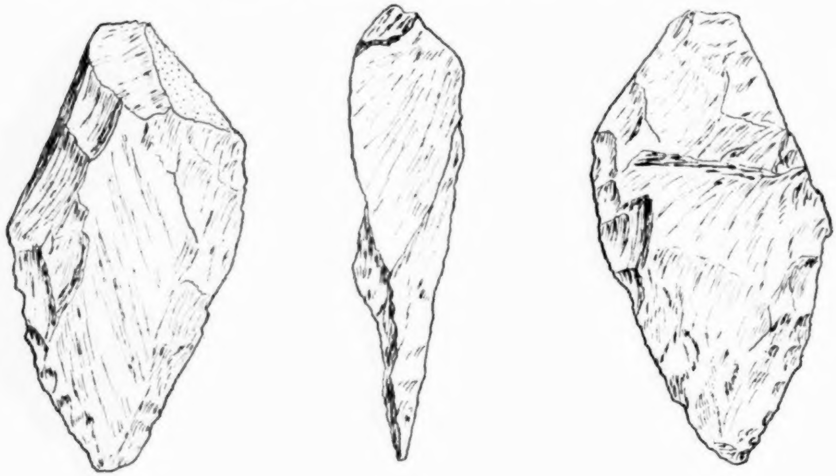


Figure 1.

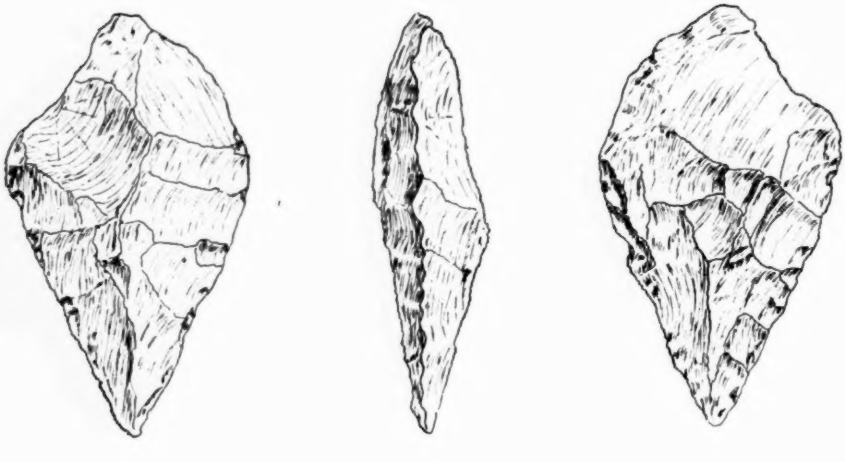


Figure 2.

TEXT-FIG. 8.

Figure 1.

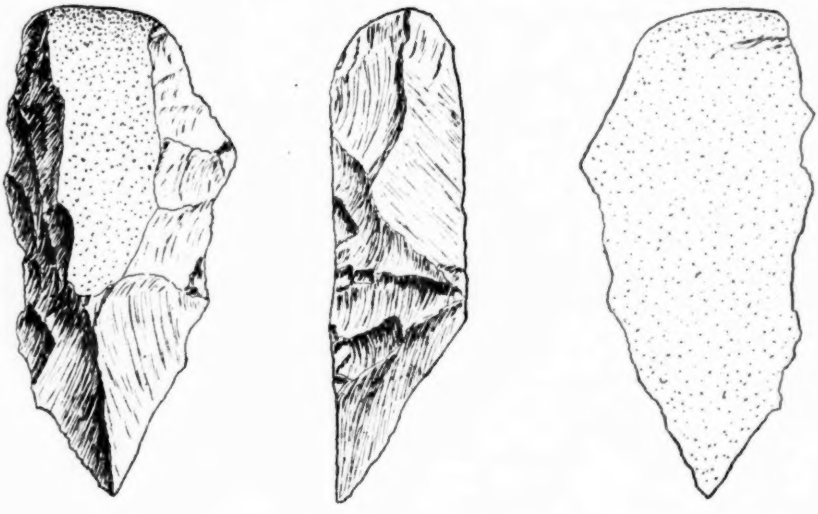


Figure 2.

TEXT-FIG. 9.

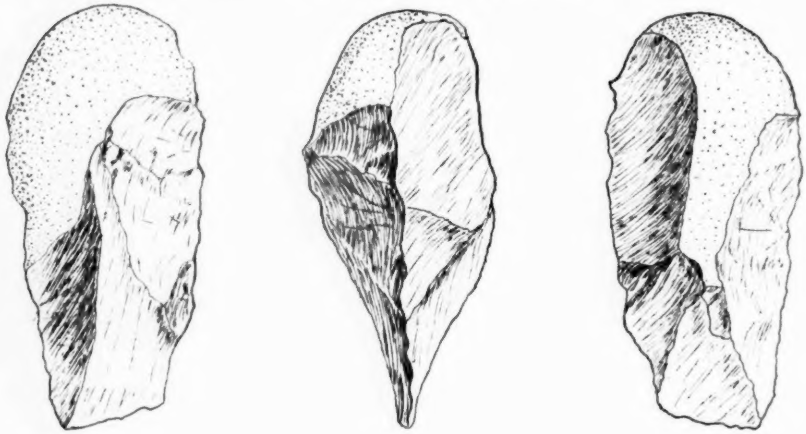


Figure 1.

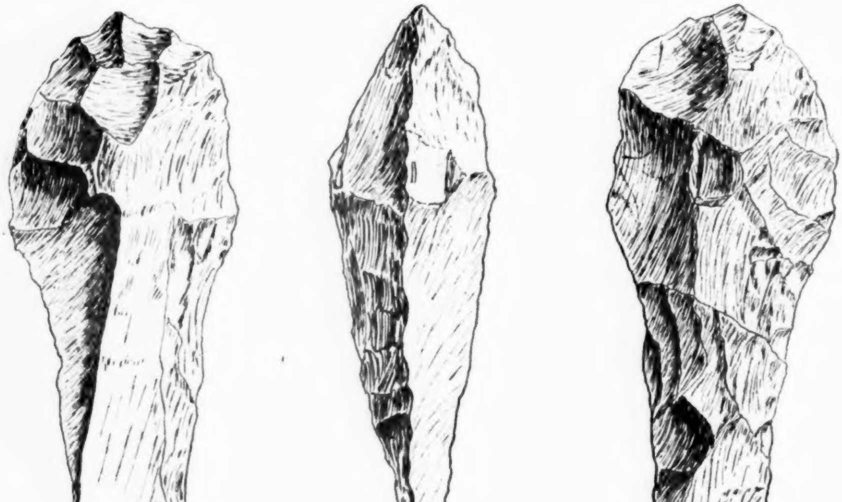


Figure 2.

TEXT-FIG. 10.

Figure 1.

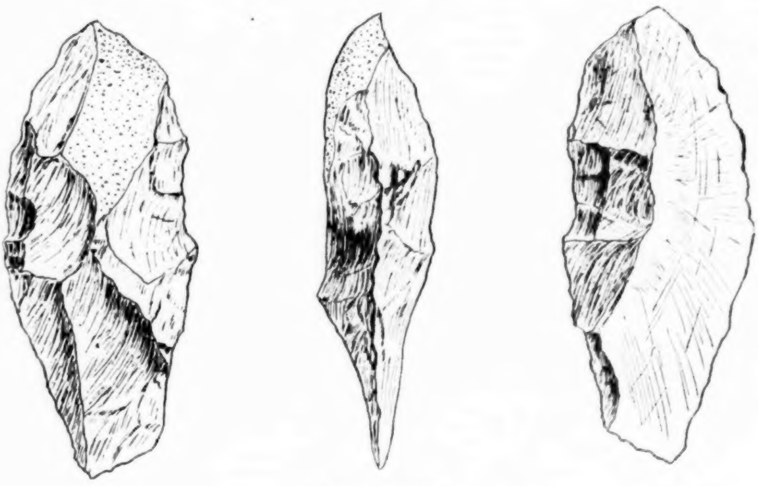


Figure 2.

TEXT-FIG. 11.

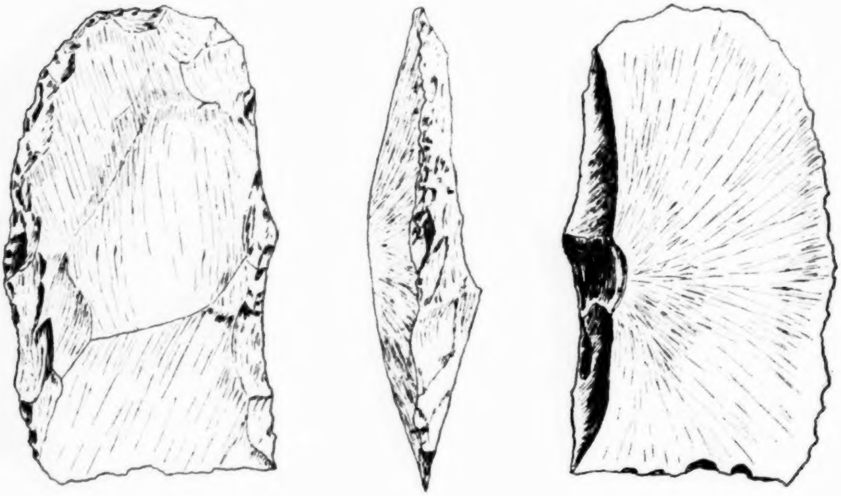


**Figure 1.**

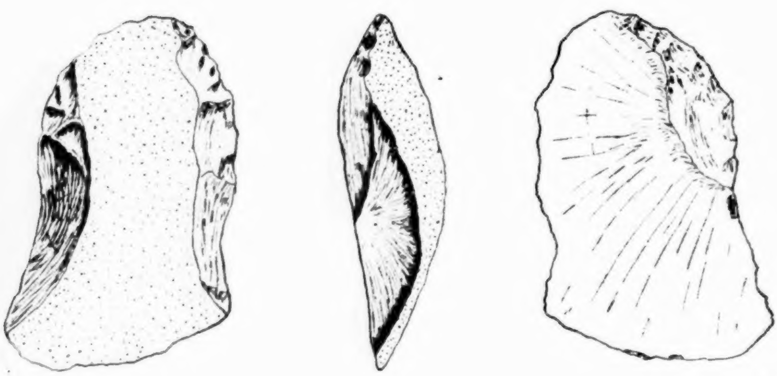
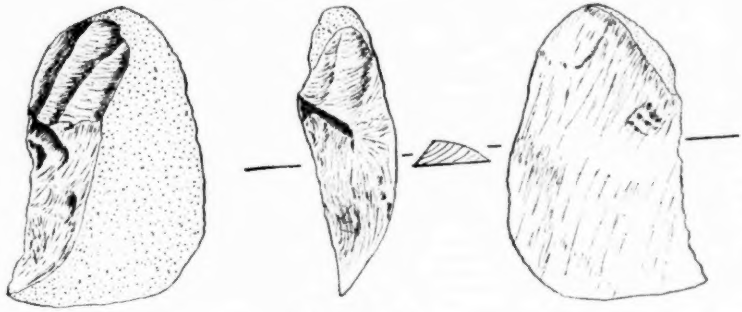


**Figure 2.**

TEXT-FIG. 12.



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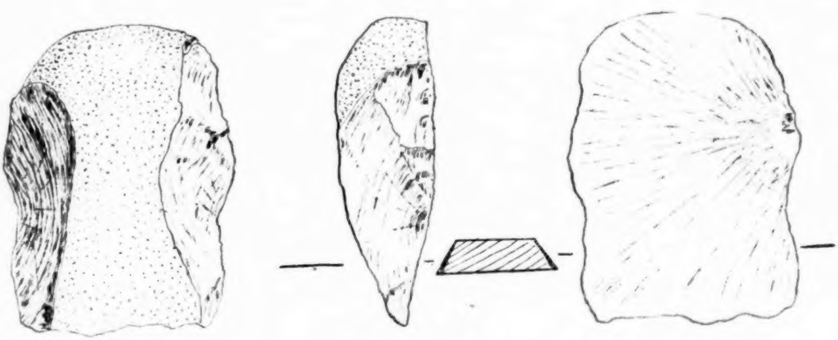


Figure 2.

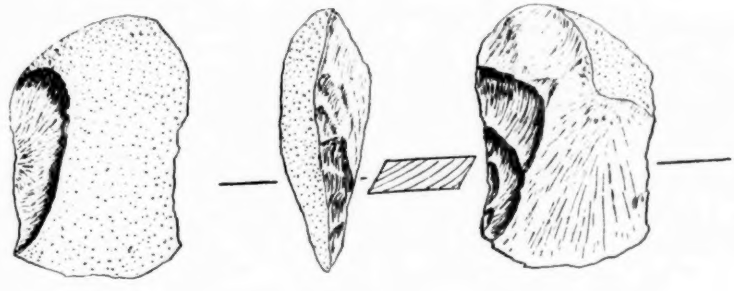


Figure 3.

TEXT-FIG. 13.

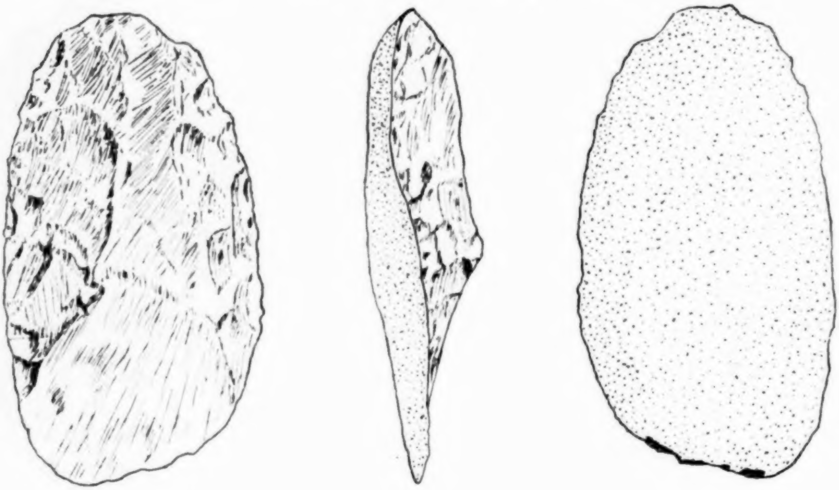


Figure 1.

Figure 2.

TEXT-FIG. 14.

Figure 1.

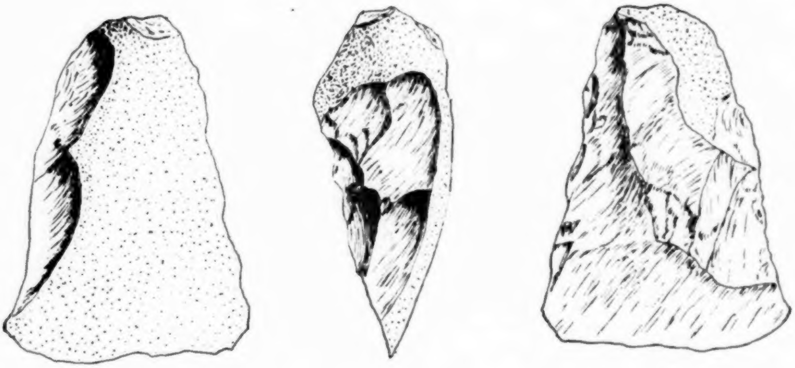


Figure 2.

TEXT-FIG. 15.

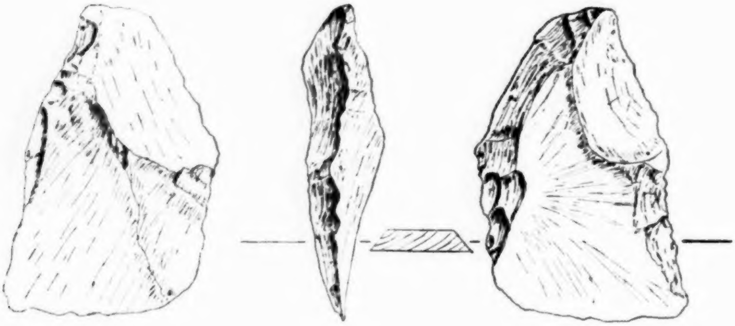
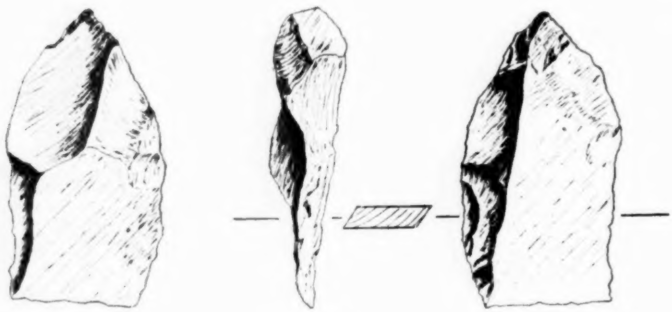


Figure 1.



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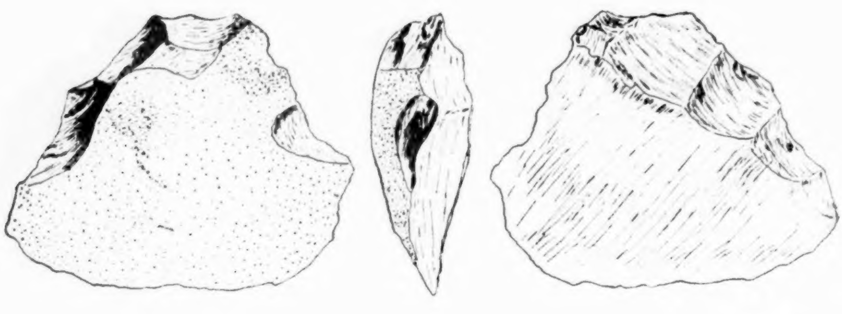


Figure 3.

TEXT-FIG. 16.

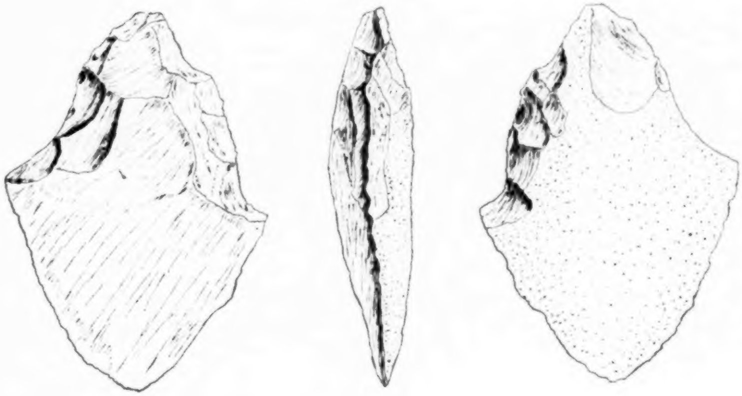


Figure 1.

Figure 2.

TEXT-FIG. 17.

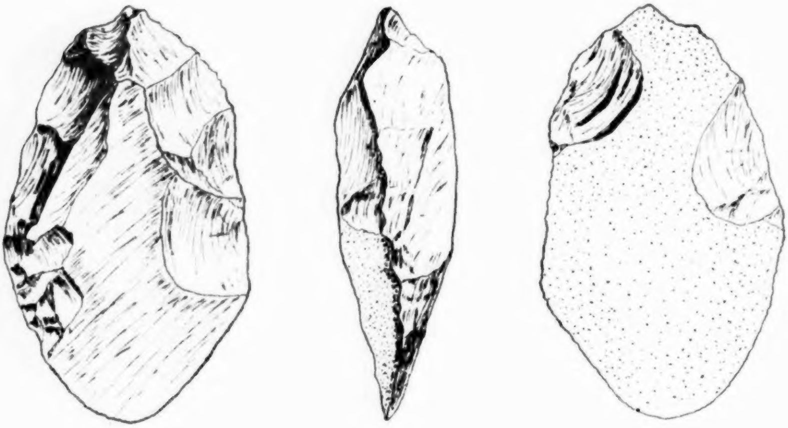


Figure 1.

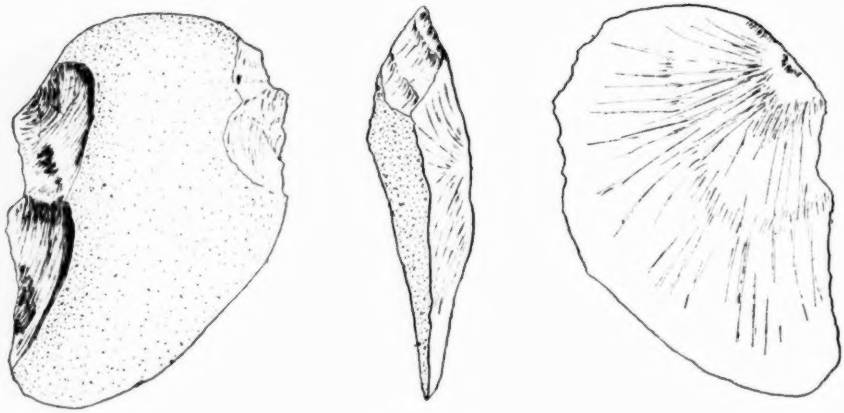
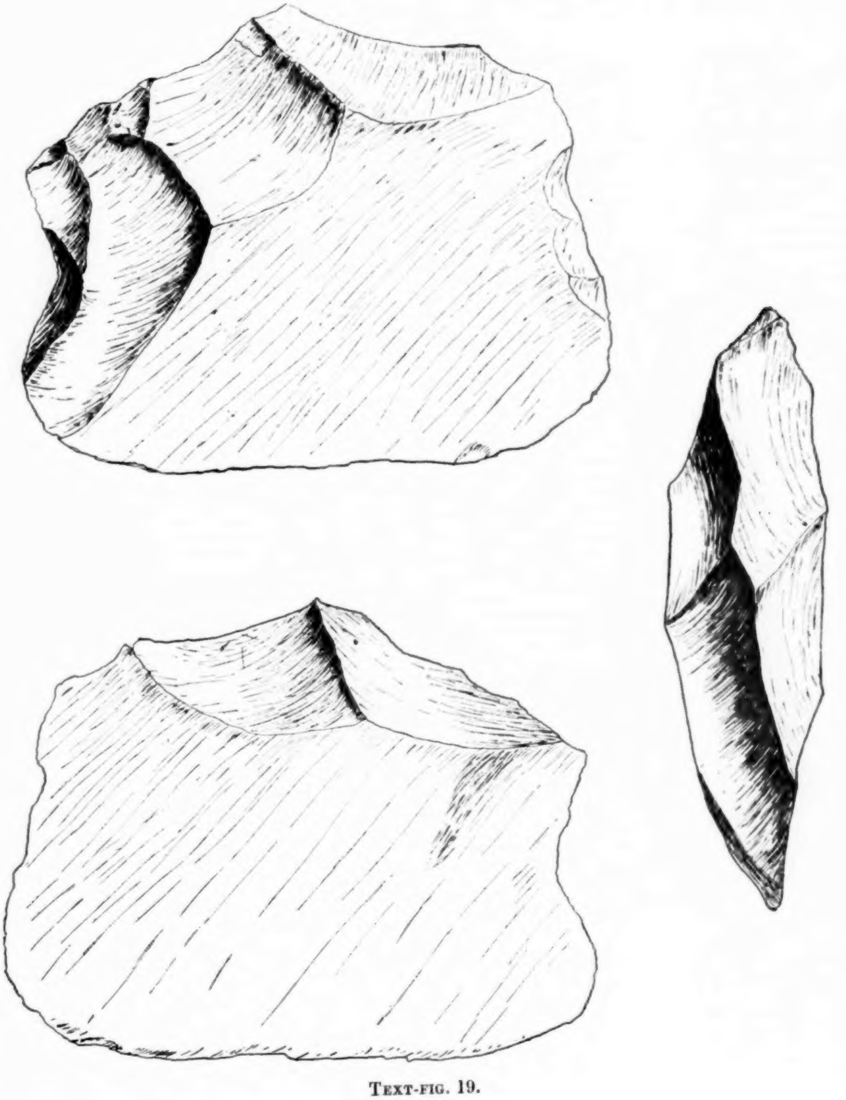
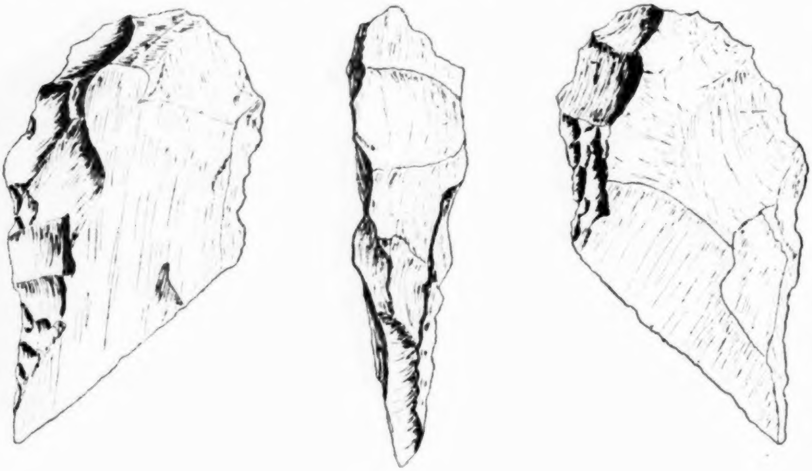


Figure 2.

TEXT-FIG. 18.



TEXT-FIG. 19.



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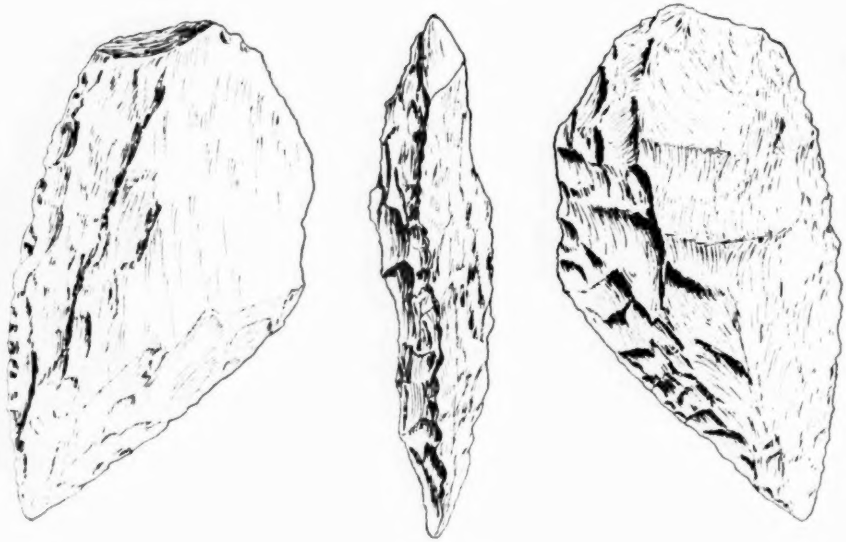

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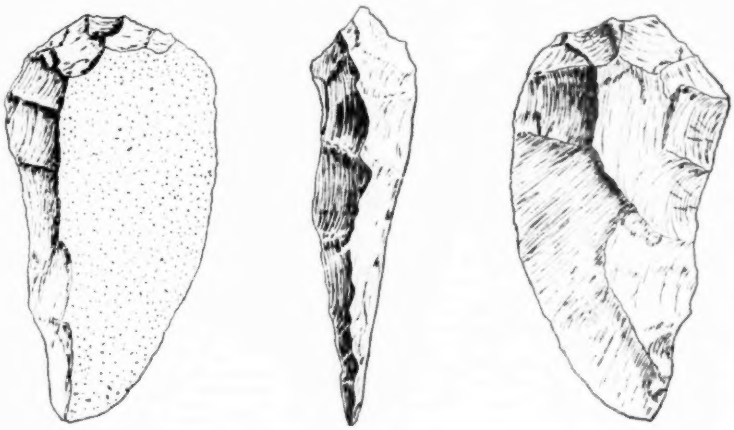
TEXT-FIG. 20.



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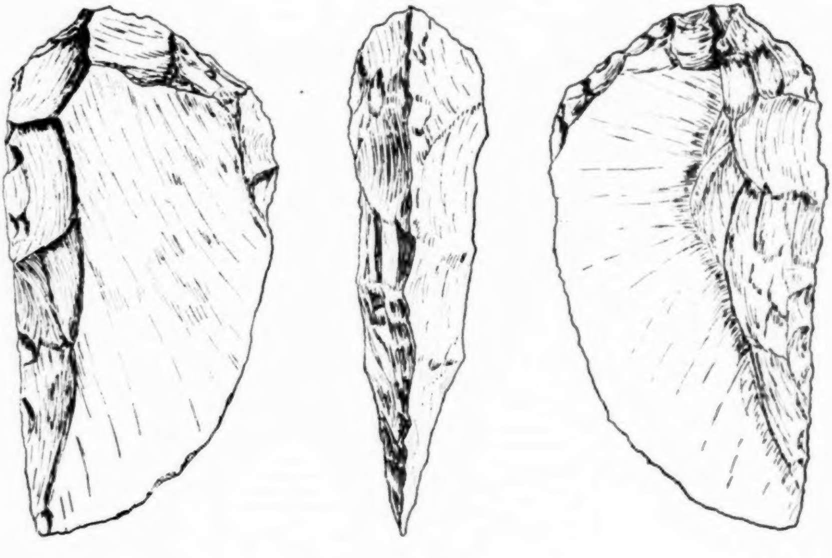

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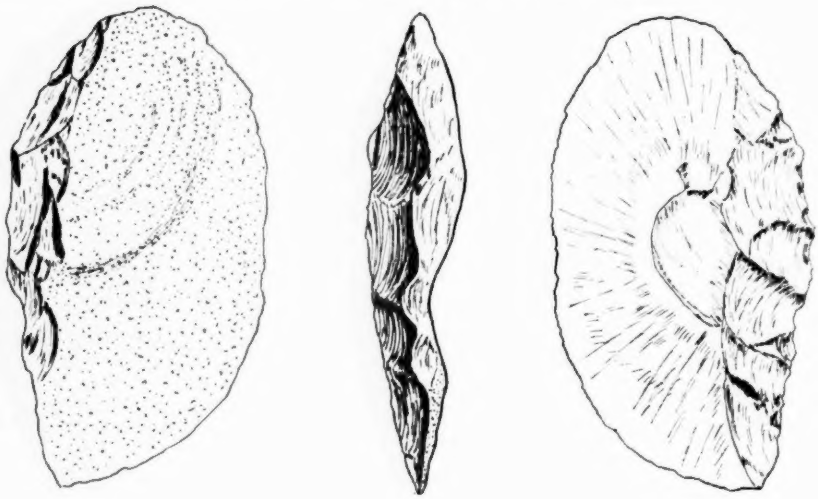

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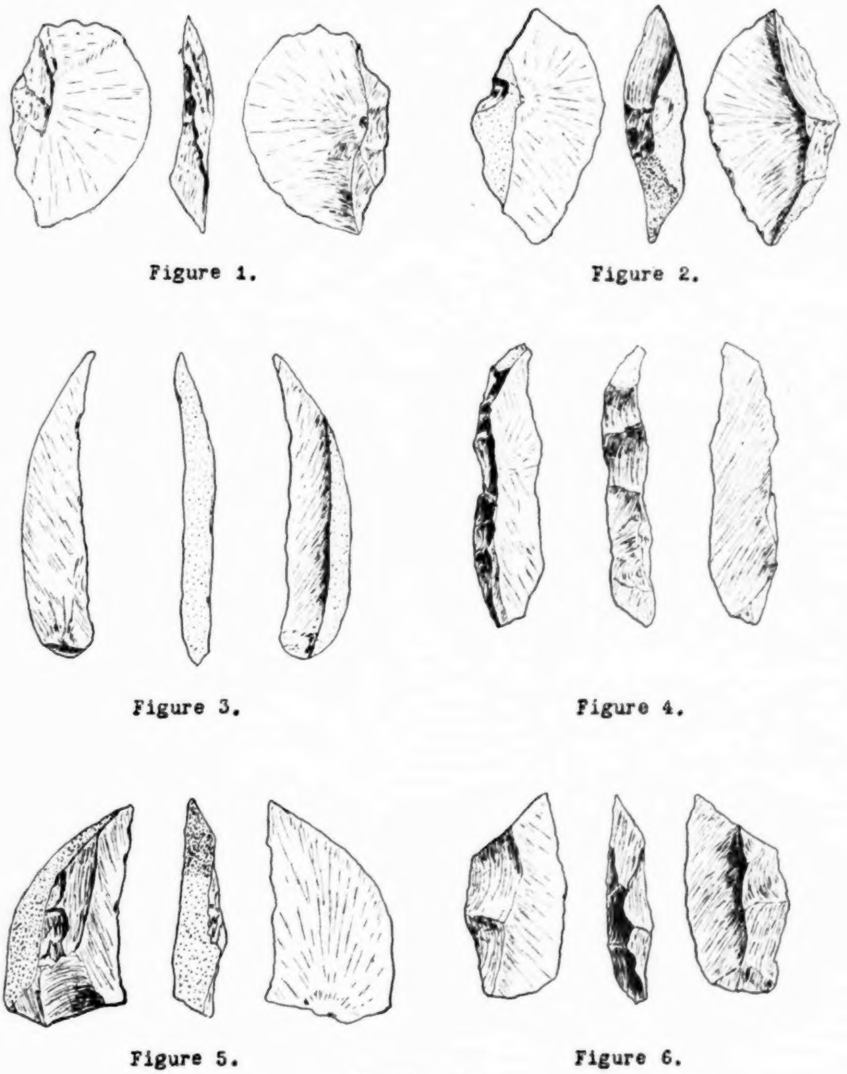


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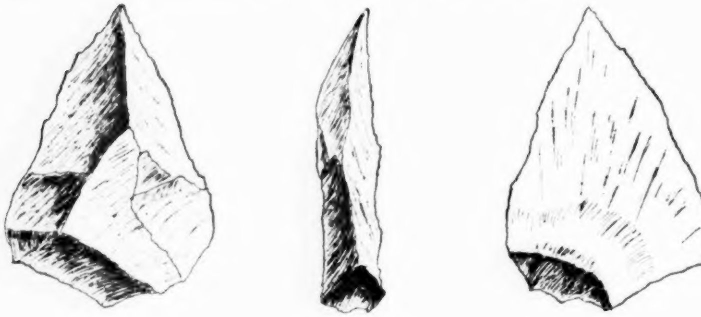

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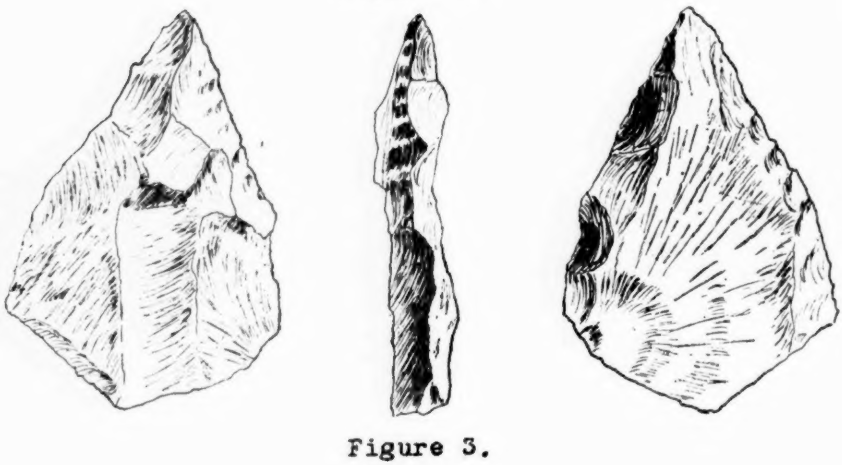

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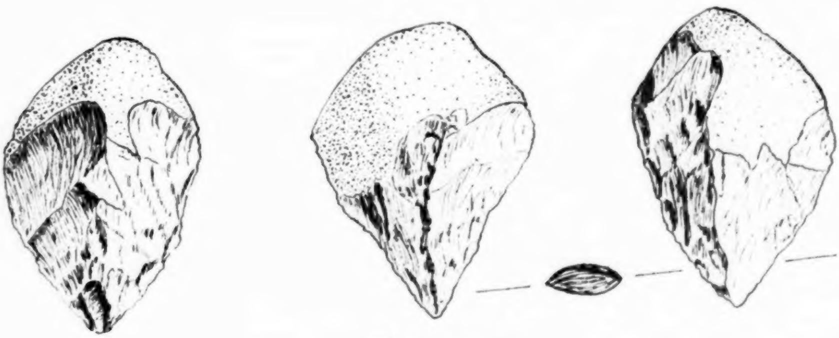
TEXT-FIG. 24.



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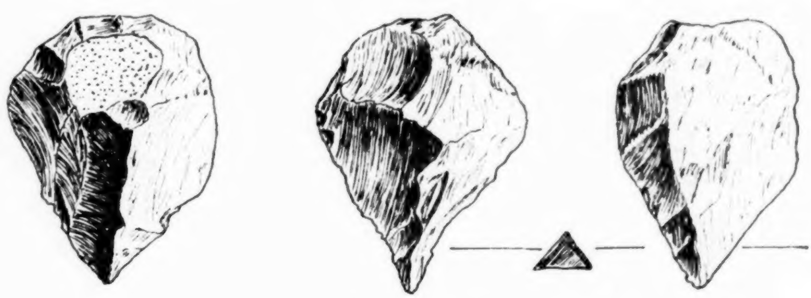

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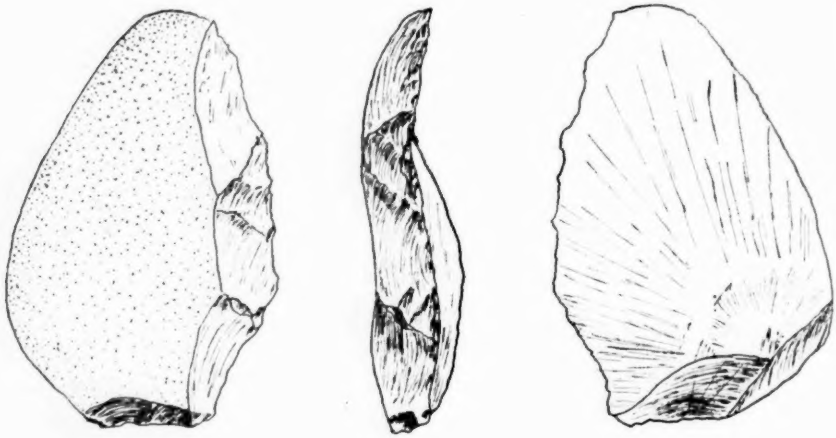
TEXT-FIG. 25.



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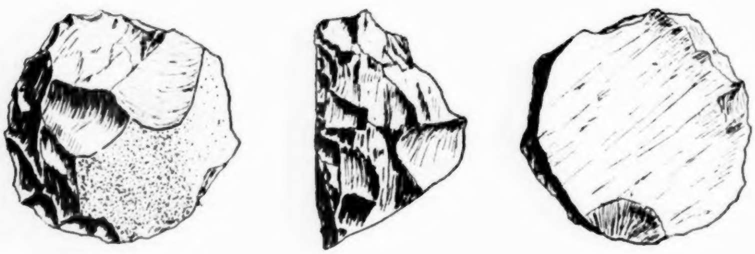

Figure 2.

TEXT-FIG. 26.

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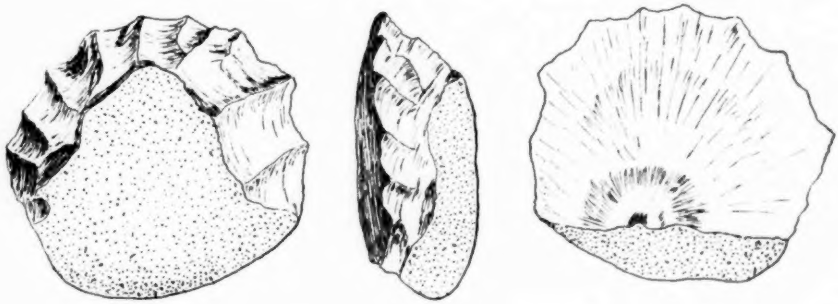

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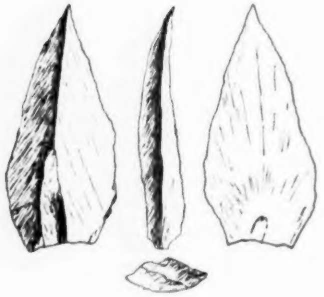

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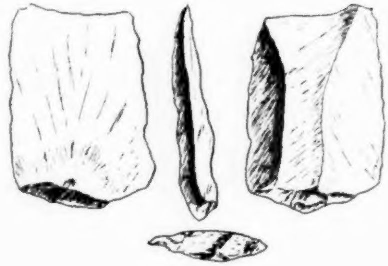

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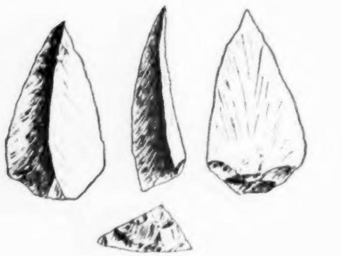

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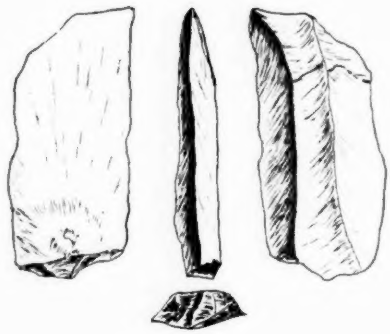

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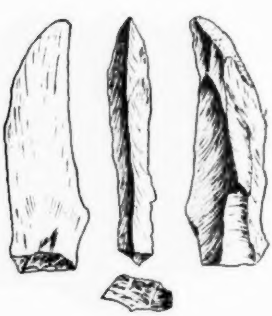

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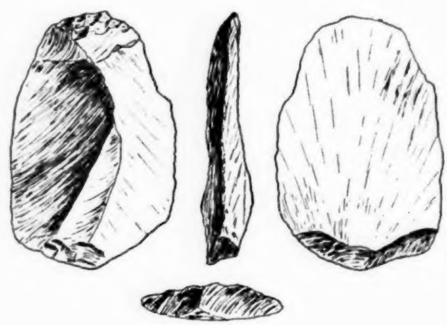

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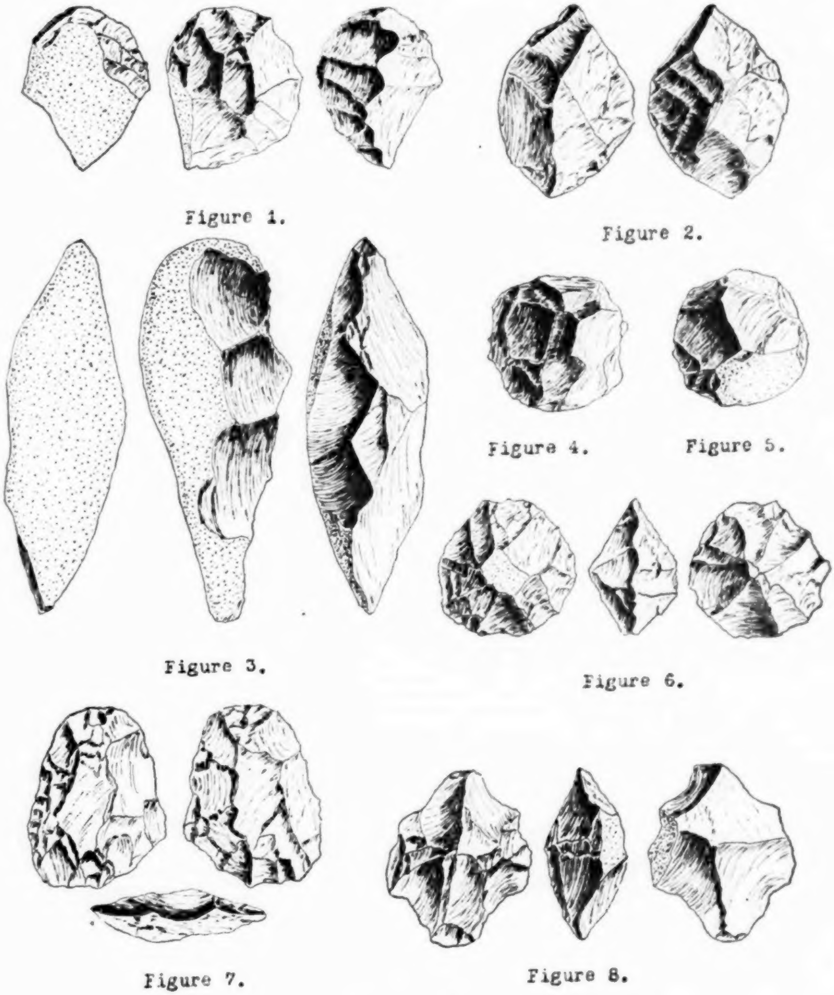
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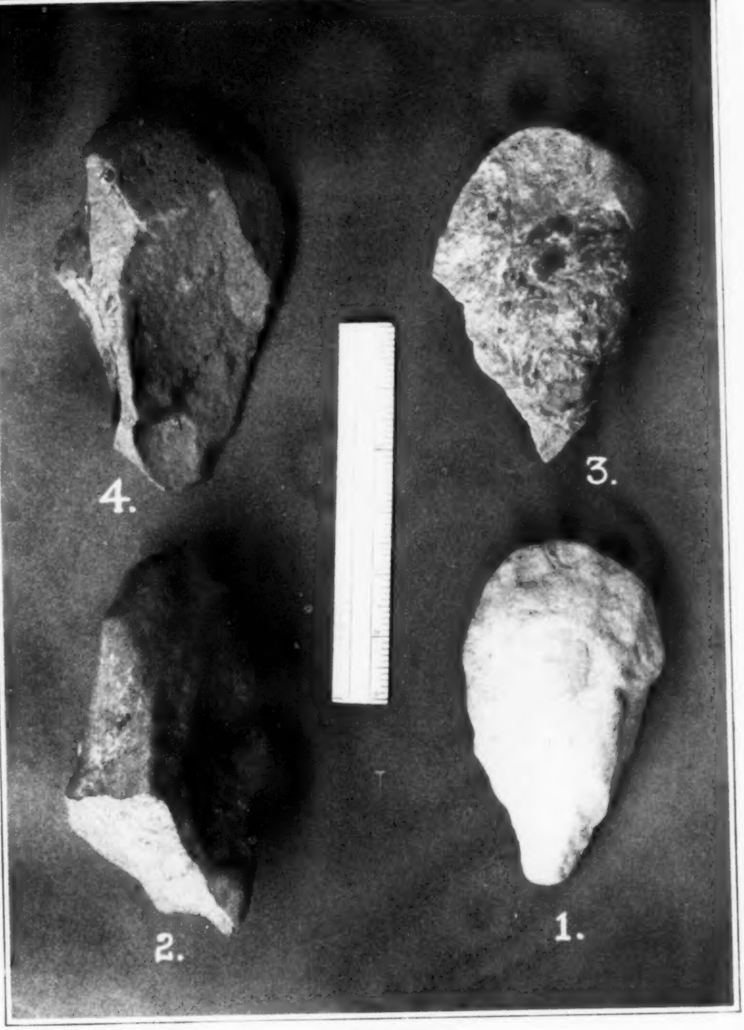
TEXT-FIG. 29.

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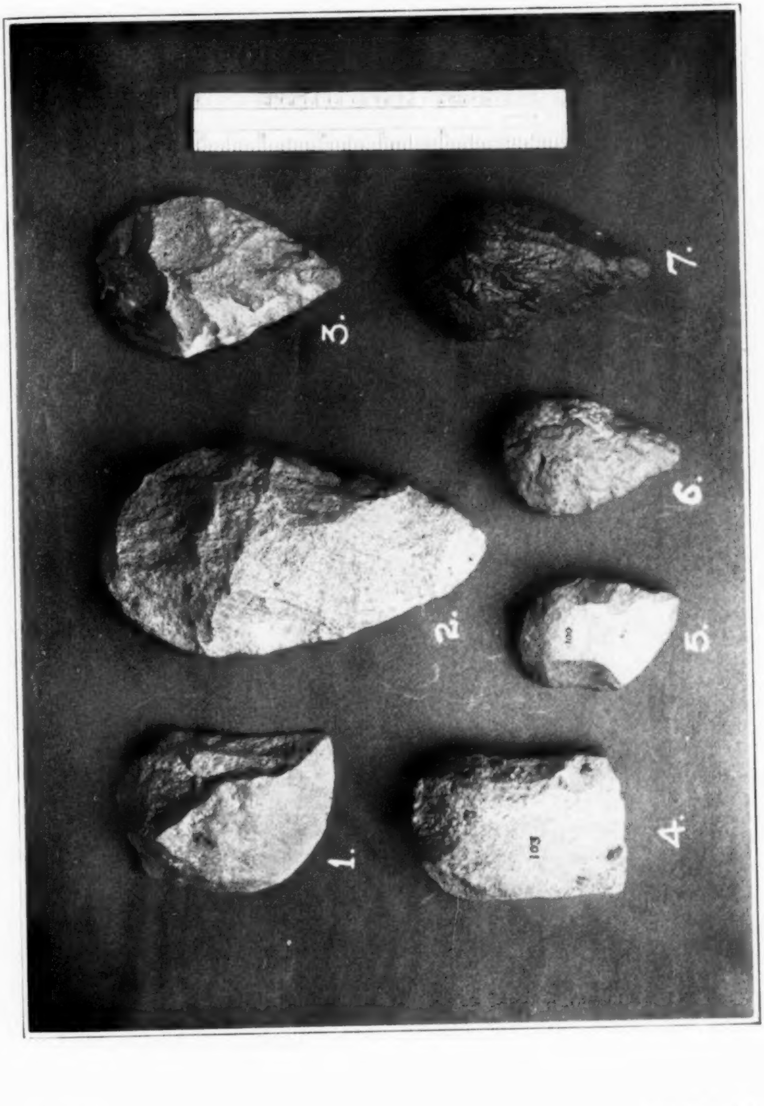


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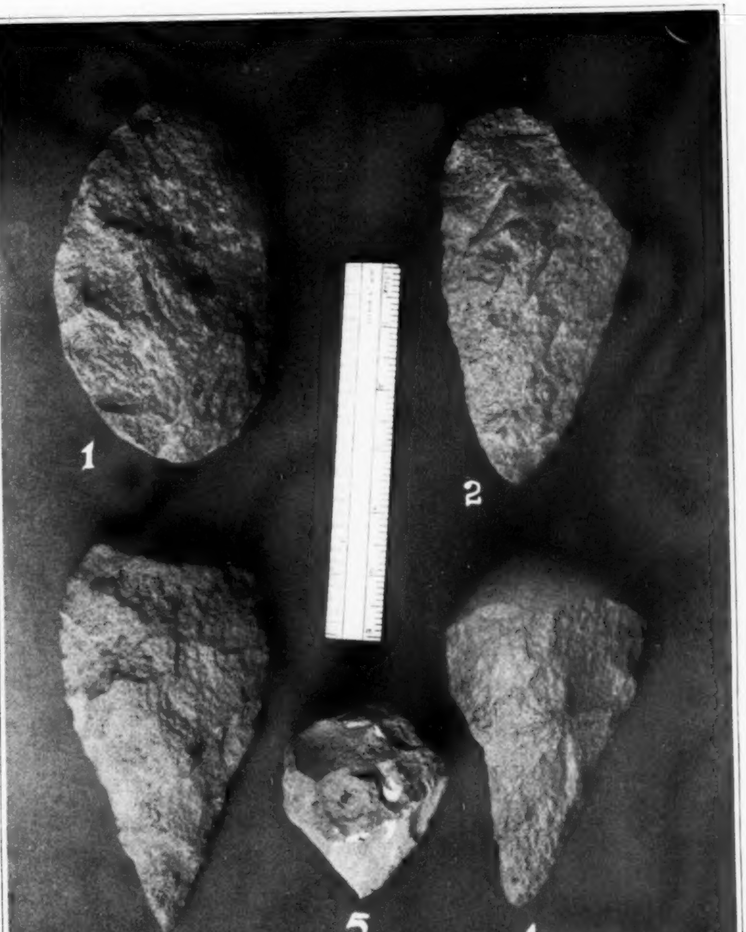


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# NEW FOSSIL ELEPHANT REMAINS FROM THE VICTORIA FALLS, NORTHERN RHODESIA, AND A PRELIMINARY NOTE ON THE GEOLOGY AND ARCHAEOLOGY OF THE DEPOSIT.

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Rhodes-Livingstone Institute, Livingstone.

(With Plates XII and XIII and eleven Text-figures.)

(Communicated by C. van Riet Lowe.)

(Read March 15, 1939.)

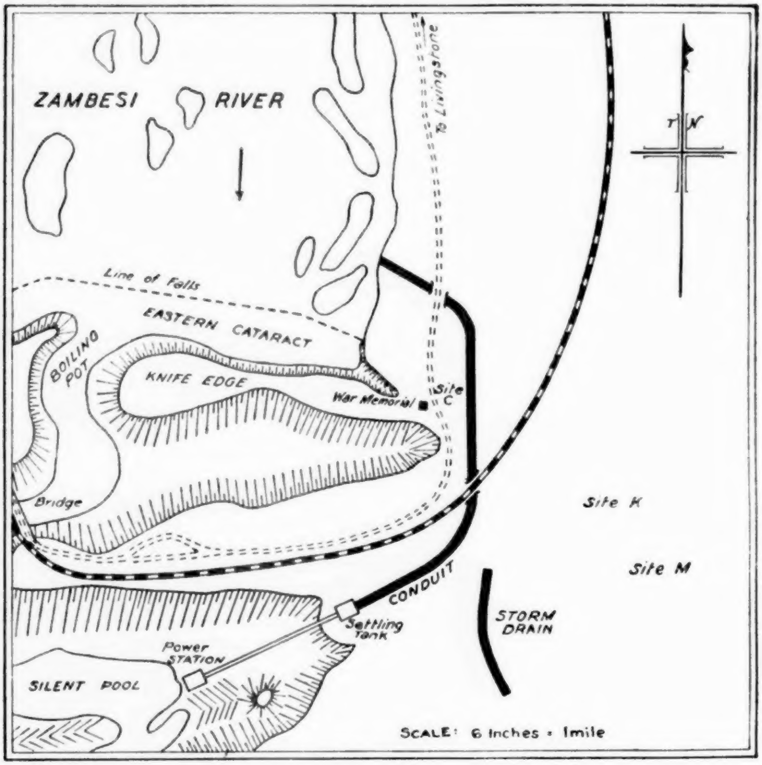
## Introduction.

One of the authors (J. D. C.) recently discovered fragments of fossil elephant teeth in a deposit exposed by recent excavations on the left bank of the Zambesi River at the Victoria Falls. As a joint examination of the associated deposits in the area of discovery had just been made by the authors, it was decided that a preliminary note on the geology, archaeology, and relationships of the deposit might appropriately accompany the description of the fossil remains. The present account is confined to the consideration of a limited area in the neighbourhood of the site of the fossil discovery only (see Sketch Map, text-fig. 1), but it is hoped that a more complete account covering a much wider area will appear in due course. It is realised that gaps may exist in the outlined succession, but it is anticipated that further work will not alter appreciably the general conclusions here arrived at.

## General Geology.

The plateau-like Victoria Falls area is underlain by the Batoka (Karroo) Basalt, and it is in these basalts that the Falls themselves and the downstream gorges have been cut. Lamplugh (1907) showed that these lower gorges were developed along belts of weakness in the basalt resulting from close jointing, "shatter belts," and opened joints filled by breccia or vein

calcite. Maufe (1929) has shown that two of the gorges, at least, were developed along shatter belts which were also lines of faulting, and he demonstrated that the transverse gorges marked former positions of the Falls, recognising eight or nine such sites including the present one.




TEXT-FIG. 1.

The basalts in the area are largely overlain by the superficial red Kalahari sand and its basal chalcedonic beds, except where surface drainage has led, in the immediate vicinity of the drainage channels, to the exposure of the underlying volcanic rock. The basal chalcedony is rarely exposed in place—it may be found *in situ* in the side of the escarpment on the north side of the river—but generally occurs as a rubble spread out over the basalt at the foot of the slopes of collapsed Kalahari sand. Fresh sections exposed in two new railway cuttings south of the Victoria Falls

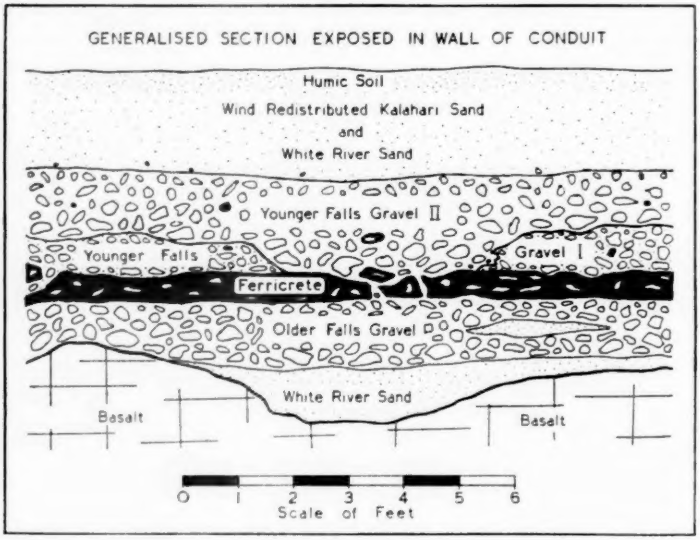
Hotel, on the Southern Rhodesian side of the Falls, show the Kalahari chalcedony lying on decomposed basalt, and it appears that it results from the irregular metasomatic replacement of an original sandy limestone, the unreplaced calcareous material having been later removed by solution. The hard flinty rock so formed was the almost invariable source of material used for making the stone implements so far recovered in the district. Consequent upon its origin, the chalcedony is full of irregular cavities, the presence of which led to the production of imperfect artifacts, and examples of these are numerous.

Overlying the chalcedony, as exposed in the cuttings, is a thin impersistent sandstone characterised by the presence of hollow pipes, and this "pipe sandstone" is interpreted as representing possibly something of the nature of a vlei deposit, the pipes being the holes originally occupied by sedge or reed roots. This sequence (Maufe, 1938) is continued by a very thin red pebbly sand-layer on the eroded surface of which was laid down a rubble deposit of "carstone" or imperfect ferricrete representing a fairly arid terrestrial deposit. This "carstone nodule bed" also contains small lumps of chalcedony and some flakes which, according to Maufe (1938), sometimes show positive and negative bulbs of percussion, secondary chipping along one or more edges and definite secondary flaking occurs in a few cases. He did not at the time of his examination recognise any type of implement, but products of human workmanship nevertheless exist, and are considered in the section of this paper dealing with the archaeology of the area.

The overlying thick deposit of bright red Kalahari sand consists of well-rounded quartz grains scattered in a finer ground mass of smaller sub-round ones, the whole being usually well compacted and generally cemented to a greater or lesser extent by red iron oxide. The individual grains, even when not cemented, are covered by a film of the red oxide, and it is to this that the deposit owes its bright red colour. The sand could not have been derived from the underlying basalt, but was evidently transported from neighbouring areas containing abundant sandstones. The sand appears to be undisturbed in the cuttings and must therefore be assigned to a post-human date. In the Falls area, particularly on the spurs between the gorges, there are thin deposits of paler, wind re-distributed Kalahari sand, and the white river sand of the Zambesi itself probably represents leached Kalahari sand derived upstream.

Gravel deposits of more recent origin occur on the left bank of the Zambesi above the Falls, and lie at a height of 8 to 25 feet above the present river-level. They are manifestly terrace or river-bed gravels, and extend for a considerable distance below the present limits of the Falls, indicating that they date back to a period when the river flowed continuously over the

area now deeply dissected by the lower gorges of the Zambesi. These gravels have already been described by Maufe (1929) as Old Terrace Gravels, but since his description appeared, exposures of the gravels in a canal leading water from just above the Falls on the left bank of the river, to the hydraulic electric generating plant situated above the Silent Pool at the end of the Third Gorge, have yielded additional information. The fossil remains were recovered from a storm drain cut for the hydro-electric




TEXT-FIG. 2.

scheme, but the succession there is fairly typical, and can be treated together with the sections exposed in the canal.

The typical section in the area (text-fig. 2) shows a thin lower band of gravel resting on an irregular, weathered, and generally rather shattered surface of basalt. White partially calcified river sand occurs between the base of the lower gravel and the basalt in certain parts, and lenticles of white sand have been noted within the band itself. Three sections situated immediately to the south of the Eastern Cataract near the War Memorial at the beginning of the Knife Edge promontory show this white calcified sand more clearly. Here the sand, the upper layers of which are ferruginous, lies in pockets eroded in the decomposed basalt, and varies in depth from 15 feet to 1 foot. It is overlain by from 1 to 4 feet of the lower gravel and sealed by a ferricrete layer. The pebbles in the gravel are chiefly of

polished or slightly roughened sub-rounded Kalahari chalcedony, but agates and quartz pebbles derived from amygdales in the basalt are also present. At the top of this band occurs an horizon of "ferricrete" and, where the lower gravel band is absent, the ferricrete rests directly on the basalt or the sand. Overlying the ferricrete locally is a "pink gravel" consisting of loosely cemented small pebbles containing rolled fragments of ferricrete and pink-stained sand. Where the ferricrete and lower gravel are absent this "pink gravel" rests directly upon the basalt, while in places it has been cut through by an overlying gravel leaving a sharp distinguishing line between the two. There is a trace of cementing iron oxides, and the material probably represents the earliest stage of ferricrete formation, although it might be the first material removed in a new cycle of erosion of the Kalahari sand. Overlying the "pink gravel" is an upper gravel band containing essentially the same pebble types as the lower gravel, but also including many pebbles of ferricrete or pebbles encrusted with ferricrete. Higher still are white and pink sands which almost certainly represent respectively river-leached and wind re-distributed Kalahari sand, and the uppermost layer consists of a brownish sandy soil containing a little humic matter.

There are thus three distinct ages of gravel, and they will be referred to here as the *Older Falls Gravel* and the *Younger Falls Gravels (I and II)*. The two younger gravels appear to belong to only one major climatic cycle with a minor change within it, there being no indications of a long interval between the two stages of aggradation. It would be incorrect to refer to these deposits as the Older Terrace and Younger Terrace gravels, since they constitute only a single terrace with a stratigraphical discontinuity between the two major phases of deposition.

It has been noted that the Older Falls Gravel does not always occur, and where it is absent the ferricrete horizon or the Younger Falls Gravels may rest directly on the basalt. In the absence of the ferricrete band due to erosion prior to the deposition of the Younger Falls Gravels, it is not always possible to determine which horizon is present. The occurrence of ferricrete in the gravel itself would indicate that the horizon is that of the Younger, but absence of ferricrete would not necessarily establish the horizon as that of the Older Falls Gravel. The ferricrete horizon is often impersistent, and even where it is distinct is greatly disturbed by the process of erosion which preceded the deposition of the overlying gravels. It is quite probable, therefore, for both gravels to be present without any discontinuity being apparent, and it is consequently impossible to establish the succession everywhere in the area.

In addition to these three horizons of river gravel aggradations, there occur at a somewhat higher level patches of apparent river gravel, often

containing ferricrete fragments or ferricrete encrusted pebbles. The occurrences are confined to small pockets or hollows on the surface, and wind-blown re-distributed Kalahari sand is sometimes associated with them. It is suggested that they may represent a flood gravel of a period later than the Older Falls Gravel deposition, and may belong to the period prior to, or separating the phases of, the aggradation of the Younger Falls Gravels. This horizon will be referred to as the *Flood Gravel*, though it is realised that the evidence for such a name is very meagre.

The sequence of events, as indicated in the area considered, shows evidence of several interesting climatic changes. The limestone which was silicified into the Kalahari chalcedony must have been laid down during a period when wet or at least marshy conditions prevailed, and it seems probable from correlation with other areas that the age of the limestone was probably Miocene or lower Tertiary. Concerning the changes which occurred in later Tertiary times no evidence is available, but towards the end of the Tertiary vlei conditions prevailed, as evidenced by the "pipe sandstone," followed by conditions of increasing aridity leading to the complete drying up of the vleis and the formation under arid conditions of the carstone nodule bed. During the period when the carstone nodule bed formed a land surface (Cooke, 1939) man was already living in the area and using the chalcedony for fashioning his implements. The Kalahari sand proper represents an arid period of extensive aeolian action, and this was followed by one of abundant rainfall and heavy erosion leading to the removal of the sand covering and the development of the original Zambesi channel. It is probable that this period of erosion was followed by a drier period, but of this no certain evidence remains. The patches of sand underlying the Older Falls Gravel may be interpreted as indicative of some overloading of the river, but this does not necessarily indicate a major discontinuity between the erosive stage resulting in the development of the river channel and the aggradation of the Older Falls Gravel, though the writers believe this to be the case.

The presence of the encrusting ferricrete on top of the Older Falls Gravel indicates clearly the onset of a period of desiccation during which the river receded at least sufficiently to expose the gravel to conditions suitable for the production of surface iron-stone. The onset of another wetter period brought about local erosion of the Older Falls Gravel surface and scattering of the ferricrete, and, drier conditions ensuing, the "pink gravel" was deposited. Wetter conditions again set in resulting in further erosion of the Older Falls Gravel and ferricrete, and also in erosion of the "pink gravel"; the flood gravel may also have been produced at this time. The aggradation resulting from another onset of drier conditions gave rise to the Second Phase of the Younger Falls Gravels containing reworked

material from the Older Falls Gravel. From the evidence available it would appear that only one wet period is present here, but it is divided into two parts by a drier interval. The declining flow of the river is further indicated by the thickness of leached river sand lying on the Younger Falls Gravels, and the presence, particularly in the upper layers, of undoubted re-distributed pink Kalahari sand shows that a period of semi-aridity or aridity permitted the extension of wind action to this area. Evidence of a later period of erosion and of subsequent deposition can be seen in a lower terrace of leached river sand, of a calcareous nature and containing many fragments of broken shells, which has been traced from about 1 mile above the Falls to a distance of about 15 miles up the river. It varies in height above the water from 10 to 15 feet, but is always lower than the Younger Falls Gravels. Increasing rainfall of the present climatic period resulted in the fresh erosion of the river-bed and the development of the present contours. In the general section this is represented by the surface soil with its contained humic matter.

The normal sequence of beds in the area examined, together with an indication of the climatic changes involved in their formation, is given in tabular form at the end of this paper. In this connection it is advisable to adopt some nomenclature which will not imply correlation with the cycles of changes worked out in other areas, and which will also permit the easy inclusion of evidence which may later arise to fill in gaps in the sequence. At the same time it must be mentioned that the use of the term "Wet Phase" does not indicate a period of continuous rainfall, but only one in which the rainfall is fairly high—the "intermittently rainy" of Barrell. For this reason the term "Pluvial Period" is regarded as misleading and is not used.

It must be pointed out that the succession and cycle of changes given is only that deduced from the limited area considered, and it will not be surprising if the examination of a wider field indicates the presence of unobserved discontinuities in the sequence. It is thought, however, that the modification will not be large, and that the present paper presents a fairly complete preliminary outline of the past history of the region. The Stone Age cultures have been correlated with the climatic changes in the table at the end of this paper, but it is considered unwise at this juncture to suggest correlations with other African areas. At the same time the close parallel between conditions in Kenya (Leakey, 1936) and in the Vaal River area (Söhnge, Visser, and Lowe, 1937) may be pointed out in passing.

### Site of Discovery of Fossil Remains.

On the basalt plateau above the Silent Pool at the confluence of the third and fourth gorges, a storm drain has been dug by the Victoria Falls Power Company in order to catch the water that during the rains would otherwise pour down upon the Power Station in the gorge below. This drain has exposed a continuous section of the Older Falls Gravel and ferricrete overlain by re-deposited sand and humic soil. The ground through which the drain has been cut is slightly higher than that surrounding it, so that the Older Falls Gravel and ferricrete, which have been eroded only round the edges of this higher ground (except for some 10 yards at the extreme north end, where a thin layer of the Younger Falls Gravels rest upon the ferricrete), are undisturbed in the area under consideration and are overlain by the re-distributed sand alone.

The drain is 250 yards long and 6 yards wide, and has been excavated to a depth of 3 feet throughout. Except at the southern end the general section exposed is as follows:—

Humic soil and re-distributed sand, 6 inches to 3 feet.

Ferricrete and iron-stone with Older Falls Gravel at base, 0 to 1 foot 6 inches.

Decomposed basalt.

Here and there small pockets of calcareous sand can be observed underneath the ferricrete and resting on the basalt, while in one place the ferricrete is overlain by a clay deposit as much as 1 foot in thickness.

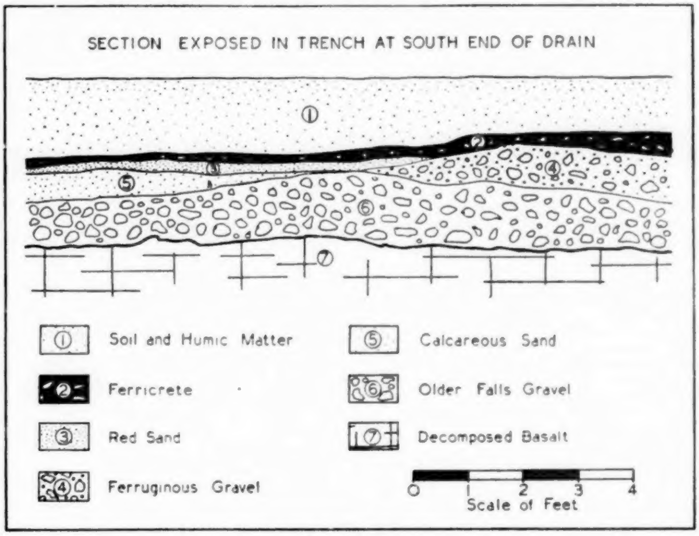
At the south end of the drain, however, there is a change, and the Older Falls Gravel is cemented and largely replaced by a calcareous river-leached sand containing rolled pebbles of basalt and chalcedony and rolled and unrolled flakes and tools. This sand overlies but merges into the Older Falls Gravel, and varies in thickness from 6 inches to 1 foot. At the top, separating it from the overlying pink sand, is a thin intermittent layer of haematite and ferricrete, which in places is entirely absent. This sand is exposed for a distance of 40 yards at the southern end of the drain, but it can also be traced over a wide area to the south, where it has been cut through by a small tributary stream and is overlain by the Younger Falls Gravels.

The material that has been excavated from the drain has been thrown up on the west bank, and it was amongst the calcareous material excavated at the southern end that the tooth specimens, here designated A and B, were found, together with a number of completely mineralised fragments of bone. Both pieces of tooth had been broken during excavation, but subsequent removal of a large part of the dump at this point failed to discover the

missing fragments, though a number of other pieces of mineralised bone were recovered.

In the bottom of the drain, about 6 feet from the place where the calcareous sand is replaced by the ferricrete and Older Gravel, the broken fragment designated C was found *in situ*.

Subsequent search, after the rains had washed clean the sides and bottom of the drain, exposed two further fragments of bone *in situ* and the complete molar tooth D at the extreme south end of the drain. One piece of bone was found embedded in the ferricrete above the Older Gravel,




TEXT-FIG. 3.

while a second piece came from the calcareous sand below a thin layer of ferricrete and haematite. One surface of the tooth had been washed clean, the other lying embedded in the firmly cemented calcareous sand, while the upper side had been exposed by erosion—it had previously been covered by a layer of humus 2 or 3 inches thick.

An exploratory trench, 14 feet long, was dug at right angles to the drain in order to determine more exactly, if possible, the stratigraphical sequence. This trench, situated 120 feet from the south end of the drain and 10 feet from its west bank, exposed the section shown in text-fig. 3, thus showing that the calcareous sand, which here overlies the Older Falls Gravel, was probably laid down during the latest period of the Earlier Wet Phase, sealed as it is by the ferricrete layer. That the fragments of bone

and tooth found should be assigned to this date is further borne out by the fact that many of them show concretions of ferricrete adhering to them.

Immediately to the south of the drain the calcareous sand is overlain by the Younger Falls Gravel II, containing rolled tools of Developed Levallois and Lower Rhodesian Stillbay types. Amongst this gravel, which here is never more than 1 foot in depth, two pieces of mineralised bone, showing signs of extensive rolling, were found. These two mineralised fragments have been almost certainly derived from the underlying deposit, which in places has been entirely removed by subsequent erosion. [H. B. S. C. and J. D. C.]

## Description of the Fossil Remains.

### *Palaeoloxodon darti* sp. nov. (Plates XII and XIII).

One complete tooth and three fragments were recovered, the fragments apparently belonging to two different teeth. Owing to their close association in the otherwise almost barren deposit, the three teeth must be presumed to belong at least to the same species, and in all probability to the same individual.

The largest fragment (A) is the posterior portion of an incompletely erupted left lower third molar, the grinding surface of the fragment being almost unworn. The smallest fragment (B) is a portion of the anterior end of a tooth worn down almost to the base of the enamel. The fractured surfaces of fragments B and A are both very fresh, and it is thought that they belong to the same molar which was broken during the excavation of the conduit. Unfortunately all efforts to recover further fragments of this tooth have proved unavailing. The third fragment (C) comprises three plates of a molar indicating slight wearing of the grinding surface. The plates cannot possibly belong to the same molar as A, and one of the fractured surfaces undoubtedly dates back to the time of deposition of the fragment. The other (posterior) surface is fresh, but no fragments have been found which would fit it. The complete tooth (D) is a left upper third molar and is only slightly damaged.

*Fragment A* (Plate XII), recovered from the dump, is the largest of the three fragments, and comprises the eight and a half posterior plates of an incompletely erupted lower left third molar. The six hindmost plates are entirely unworn, the seventh shows faint indications of wear in the centre, and the eighth plate is very slightly worn. The roots are attached to fragmentary remains of the jawbone, and it is consequently difficult to determine the precise height of the plates. The fractured surface of the ninth plate is unweathered and fresh.

As preserved, the greatest length of the eight and a half plates, measured

in a straight line, is 212 mm., giving a length-lamellae quotient of 25. The lamellar frequency varies from 3·9 in the front part of the tooth to 4·2 in the back part. The individual lamellae taper markedly upwards and curve somewhat anteriorly. The thickest plate (8th) measures 21 mm. near the root and only 12 mm. at the grinding surface. The thickness of cementum between the 7th and 8th plates ranges from 8 mm. at the base to 5 or 6 mm. at the grinding surface, and the average thickness of the cementum apparently decreases posteriorly. The greatest width, including cementum, is 95 mm., and the width of the 7th plate at the grinding surface is 61 mm. The enamel, as exposed on the 8th plate, is 4 mm. thick, and the pattern consists of several islets in contact and which, with further wear, would probably coalesce to form a narrow oblong, possibly slightly crimped, and initially showing little dentine.

The height of the 8th plate, measured from the root to the grinding surface, is about 160 mm., and, since the plate is just coming into wear, this is probably about the maximum height of any plate. On the broken surface of the 9th plate, the height of the tooth from the base of the enamel to the grinding surface position is about 130 mm.

*Fragment B*, recovered from the dump, is the greater part of three anterior plates the foremost of which is worn down below the base of the enamel. A fracture exposes the enamel of the other two plates almost in mid-section, and shows it to form sharply **V**-shaped valleys with only a thin (1 mm.) line of cementum. The distance between the centres of the enamel valleys on the grinding surface is 21 mm. The enamel is 4 mm. thick, and the strip of dentine exposed between the enamel ridges is 12 mm. wide. The pattern of the grinding surface is unfortunately obscured by fractures, but the enamel ridges, as far as can be seen, run directly across the tooth and are almost straight. In the least worn plate, the distance from the base of the enamel to the root is 45 mm., and the greatest height of the fragment from the root to the grinding surface is 78 mm.

*Fragment C*, found in the calcareous sand at the bottom of the drain 125 feet from its south end, comprises most of three central plates of a molar manifestly not the same as that from which A and B come. All three plates are only very slightly worn, the posterior one being worn only in the centre, and they form part of an upper molar, probably the right upper third molar. The greatest "length" of the three plates is 60 mm. near the root, giving a length-lamellae quotient of 20 and a lamellar frequency of 5. The lamellae taper upwards and curve somewhat posteriorly. The thickest plate measures 19 mm. near the root and 10 at the grinding surface, and the cementum between the central and anterior plates is 5 mm. thick at the base and the same at the grinding surface. The greatest width, including cementum, is 93 mm., and the

width at the grinding surface of the anterior plate is 65 mm. The enamel is 4 mm. thick, and the pattern identical with that of fragment A.

The height of the central plate from the root to the grinding surface is 209 mm. The extent of the enamel cannot be measured, but it certainly extends more than two-thirds of the way down towards the root.

*Specimen D* (Plate XIII), recovered from the calcareous sand at the extreme south end of the drain, is a complete upper left third molar somewhat damaged by weathering and removal from the rather hard matrix. It comprises 12 1/3 plates of which the anterior 9 1/3 are in wear, the foremost being worn down completely to its base. Unfortunately the 4 posterior plates are damaged near the grinding surface and the pattern is obscured.

The greatest length of the 12 1/3 plates, measured in a straight line, is 234 mm., giving a length-lamellae quotient of 19. The lamellar frequency varies from 4·9 in the anterior portion to 5·5 in the posterior portion, and the difference is accountable mainly to anterior thickening of interlamellar cementum. The individual lamellae taper slightly upwards and curve somewhat anteriorly. The thickest plate (4th) measures 17 mm., and the average width of interlamellar cementum is 5–6 mm. The greatest width of the molar, including some cementum, is 94 mm., and the greatest width at the grinding surface is 81 mm.

The enamel is 3·5 to 4 mm. thick, and the pattern consists of well-raised ridges running almost directly transversely across the tooth, with a tendency towards the formation of a posteriorly arched crescentric form in the medial portion of the tooth. Posteriorly the enamel shows a tendency to break up into islets, but owing to the damage to this portion of the specimen the transition cannot be observed. The lamellae are medially somewhat wider than laterally, and the enamel is not markedly crimped.

The greatest height is 219 mm. measured from the base of the root to the grinding surface, and since this plate (9th) is the least worn, that is presumably the maximum height of the molar.

## Discussion.

If fragments A and B belong to the same molar and the two fragments are placed in their probable relative positions, it appears that at least four plates must have intervened between them, so that the entire molar would probably comprise about 15 plates. This figure should be borne in mind, though no direct deductions can be made from the figure, as it cannot be established that the two fragments do belong to one molar only.

The hypsodonty and general relationships of cementum and lamellae at once bring the specimens within the generic limits of ***Archidiskodon*** and ***Palaeoloxodon***.

The principal measurements of the complete molar D and the two fragments A and C, and the corresponding measurements on all the various species assigned to these two genera in South Africa, are tabulated below and arranged in order of decreasing length-lamellae ratios. The archidiskododont specimen to which Osborn (1934) gave the new generic name *Metarchidiskodon* is included, and the data for the worn and damaged fragment B is added for the sake of completeness, though the measurements are of little value by themselves.

The columns refer to the following particulars:—

Pos = Position to which the molar is assigned, the customary abbreviations, *e.g.* $RM^3$ = Right Upper Third Molar, $LM_3$ = Left Lower Third Molar, etc., being used.
No. = Number of lamellae preserved.
Lg = Greatest length of specimen measured in a straight line.
H = Height of deepest plate.
Bg = Greatest breadth of widest lamella.
En = Thickness of enamel.
Lf = Lamellar frequency (*i.e.* number of lamellae in 100 mm.).
R = Length-lamellae ratio.

Out of all these listed species, the only ones whose general and enamel characters are at all comparable with the specimens A, B, C, or D here described are *Archidiskodon yorki*, *Palaeoloxodon transvaalensis*, *P. sheppardi*, and *P. hanekomi*. The fragment C agrees closely with the data for *Archidiskodon yorki*, almost the only difference being the greater width of Dart's species. The fragment A (and B) is of a lower molar, whereas the described species are almost all upper molars, thereby rendering comparison a somewhat difficult matter. For this reason specific identification must rest mainly on the complete molar D.

It is geologically so very improbable that the three fragments found so closely associated with the complete molar in an otherwise almost barren deposit should not belong at least to the same species, and probably to the same individual, that it must be assumed that they do. The apparently wide differences in measurements between the different specimens are not so large as to show that they must belong to different species, though it is probable that they would have received different specific names had they been found separately. It may be pointed out in this connection that Osborn (1934) has suggested that *Palaeoloxodon transvaalensis* (Dart) and *P. sheppardi* (Dart) are probably synonyms, and it seems very probable that careful re-examination of all the described species listed above would indicate the identity of others of them, the characters regarded formerly as specific being accountable on a basis of sexual differences, variation within a species, and variation between different teeth in an

| | Pos. | No. | Lg. mm. | H. mm. | Bg. mm. | En. mm. | Lf. | R. |
|---|---|---|---|---|---|---|---|---|
| *Metarchidiskodon griqua* (Haughton)† 1922 | LM$^3$ | + 3 + | 97 | 81 | 86 | 3–4 | 3 | 32 |
| *Archidiskodon vanalpheni* Dart 1929 . | LM$^3$ | $7\frac{1}{2}$ + | 234 | 129 | 112 | 3–4 | 3–3·5 | 31 |
| *Archidiskodon loxodontoides* Dart 1929 . | LM$^3$ | + $4\frac{3}{4}$ + | 149 | 112 | 94 | 3–4 | 3·5 | 31 |
| *Archidiskodon proplanifrons* Osborn 1934 . | RM$^3$ | 6 | 179 | 55 | 104 | 5 | 3·5 | 30 |
| *Archidiskodon milletti* Dart 1929 . . | LM$^3$ | 8 + | 222 | 118 | 108 | 3–4 | 3·5 | 28 |
| *Archidiskodon broomi* Osborn 1928 . . | M$^3$ | 6 | 168 | 152 | 109 | ? 3 ‡ | 3·5–4 | 28 |
| *Archidiskodon subplanifrons* Osborn 1928 . | RM$_3$ | $5\frac{3}{4}$ + | 153 | 64 | 101 | 4 | 4 | 27 |
| *Palaeoloxodon transvaalensis* (Dart)† 1927 . | RM$^3$ | + $9\frac{1}{2}$ | 246 | 231 | 110 | ? 3 ‡ | 4 | 26 |
| Fragment A . . . . . . | LM$_3$ | + $8\frac{1}{2}$ | 212 | 160 | 95 | 4 | 4 | 25 |
| *Palaeoloxodon andrewsi* (Dart)† 1929 . | LM$_3$ | 6 * | 164 * | 48 * | 83 * | 4–5 | 4 | 24 |
| *Palaeoloxodon sheppardi* (Dart)† 1927 . | LM$^2$ | 11 | 246 | 188 | 100 | ? 3 ‡ | 4·5 | 22·5 |
| Fragment B . . . . . . | LM$_3$ | + 3 + | 67 | .. | .. | 4 | 5 | 22 |
| *Archidiskodon yorki* Dart 1929 . . | ? | + 2 + | 41 | 210 * | 114 | ? 4 ‡ | 5 | 21 |
| Fragment C . . . . . . | RM$^3$ | + 3 + | 60 | 209 | 93 | 4 | 5 | 20 |
| *Palaeoloxodon yorki* (Dart)† 1929 . . | RM$_3$ | 9 | 180 | 115 | 79 | 2–3 | 5–6 | 20 |
| *Palaeoloxodon kuhni* (Dart)† 1929 . . | LM$_3$ | 5 | 96 | 100 | 75 | 2 | 6 | 19 |
| Specimen D . . . . . . | LM$^3$ | $12\frac{1}{3}$ + | 234 | 219 | 94 | 3·5–4 | 4·9–5·5 | 19 |
| *Palaeoloxodon hanekomi* (Dart)† 1929 . | RM$^3$ | 17 | 310 | 220 · | 102 | ? 4 ‡ | 4·5–5·5 | 18 |
| *Palaeoloxodon wilmani* (Dart)† 1929 . | LM$_3$ | 7 + | 115 | 128 | 70 | 1·5–2 | 6 ? | 17 |
| *Palaeoloxodon archidiskodontoides* . . | LM$^3$ | 9 + | 148 | 145 | 94 | 2·5–3 | 6·5 | 15·5 |
| (Haughton)† 1932 . . | RM$^3$ | 7 | 108 | 98 | 94 | 2·5–3 | 6·5 | 15·5 |

† Generic reference altered by Osborn (1934). * Estimated measurement. ‡ Estimated measurement (from figure, not specimen).

individual. It has recently been shown that the specific identifications of fossil pig teeth from South Africa have to a large extent been based incorrectly on features which prove to be accountable to variation within the species (Middleton Shaw, 1939). In the case of the modern elephant *Loxodonta africana*, examination by Haughton (1932) has shown the great variation which exists within the species, and an excellent example of variation between upper and lower teeth in the same individual is to be seen in the case of *Palaeoloxodon antiquus italicus*, the measurements for which are given below from the original description by Osborn (1931):

| | No. | Lg. | H. | Bg. | Lf. | R. |
|---|---|---|---|---|---|---|
| Right Upper Molar $RM^3$ . . | 20 | 295 | 190 | 80 | 6–7 | 14·7 |
| Right Lower Molar $RM_3$ . . | 18 | 306 | 128 | 80 | 4–5 | 17 |

On the basis of such variation the molar D and fragment C would be well within the limits for the upper molars of an individual in which fragment A (and B) belonged to a lower molar.

The hypsodonty of the molar D is considerably greater than that of *Palaeoloxodon transvaalensis* (= *sheppardi*) and the angle of wear is very different, though the enamel patterns are somewhat similar, and there is no doubt that the new molar is a distinct species. On the other hand, the hypsodonty is not nearly so marked as in *P. hanekomi*, the number of plates is smaller and the enamel pattern is considerably different. In many respects the new species is intermediate between *P. transvaalensis* and *P. hanekomi*, and certainly belongs to the same group as those two species.

There seems no doubt that the specimens described here as recovered from the Victoria Falls area in a calcified sand deposited during the declining stages of the period termed in this paper the Earlier Wet Phase, constitute a new and distinct species of the genus *Palaeoloxodon*. It is proposed to name the new species *Palaeoloxodon darti* Cooke, in honour of Professor Raymond A. Dart and in recognition of his pioneering work in the study of South African fossil Proboscidea. The holotype specimens of the new species are the upper left third molar referred to as specimen D, and the portion of the lower left third molar referred to as fragment A. These type-specimens are in the Museum of the Rhodes-Livingstone Institute, Livingstone, Northern Rhodesia, and casts are kept in the Department of Geology and in the Department of Anatomy of the University of the Witwatersrand, Johannesburg.

The fragment of an upper molar, fragment C, is not regarded as type material owing to its imperfect nature, but it is referred to the new species as a paratype. It has already been pointed out that the fragment C agrees closely with the data for *Archidiskodon yorki* except for the narrower

plates of the new species. From its position in the tabulation given, it is apparent that *A. yorki* should be referred to *Palaeoloxodon*, and since there is a close agreement between it and the corresponding plates of *Palaeoloxodon hanekomi*, it seems advisable to refer the specimen described as *Archidiskodon yorki* to *Palaeoloxodon hanekomi* rather than to create another species on such fragmentary material.* This would also be in agreement with the relationship to the new species.

The bone fragments recovered from the same deposit are too fragmentary to be of value, but it may be mentioned that they include portions of rib bones, a fragment of a long bone, possibly the ulna, a portion of a fibula, and a fragment which may be part of the axis.

The general affinities of the teeth suggest that they are Middle or Upper Pleistocene. [H. B. S. C.]

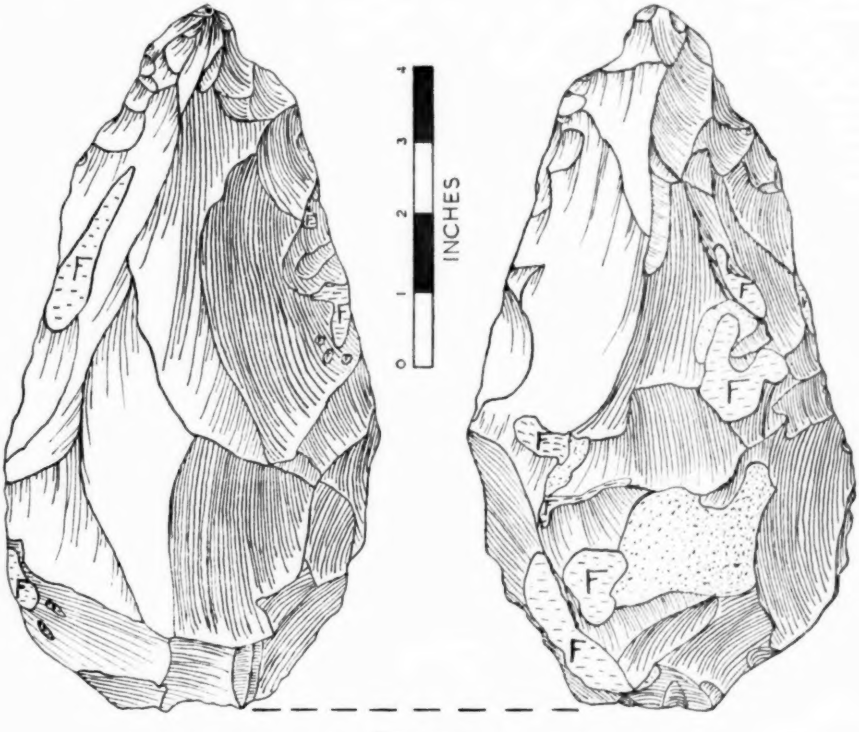
## The Archaeology of the Immediate Area.

In this preliminary account it is proposed to summarise briefly the general conclusions that have been reached from a year's study of the archaeological evidence in the vicinity of the Victoria Falls, and to show how the implements from the storm drain where the faunal remains were found are to be correlated with this wider area.

The earliest types of tools that can be definitely ascribed to human agency have been found on and in the carstone rubble bed recorded by Mr. H. B. Maufe (1938) at the base of the Kalahari sand in the two new railway cuttings to the south of the Victoria Falls Station. In view of Mr. Maufe's discovery of chalcedony flakes showing positive and negative bulbs of percussion, an intensive search was made in this rubble bed and numbers of similar flakes were found. These flakes show an unfaceted, inclined striking platform of an average angle of 120°, one surface being a main flake surface with a comparatively flat bulb of percussion, while the other is formed by the intersection of the scars of several bold flakes struck from two or more sides. A few flakes showing a primitively faceted striking platform were also found (text-fig. 6, No. 3). The faceting is probably fortuitous, as these flakes appear to be the ones that have been removed from the ventral surface of a type of "nosed" core tool after the nose, which formed the striking platform, had been trimmed; they may, however, be the flakes derived from an intentionally prepared core. Far the greater majority recovered from the bed are primary flakes devoid of secondary working, but one or two show signs of use on one or more edges (text-fig. 6, No. 6). These flakes had been struck from cores which show signs of having been used as tools subsequent to the removal of the flakes,

* A conclusion with which Professor Dart now agrees.

and the material from which they are made was almost certainly derived from the basal bed. Two distinct patinas, a light brownish green and a white, are exhibited by these flakes and cores. The flakes exhibiting a white patination, which is nearly half a millimetre thick, are found for the

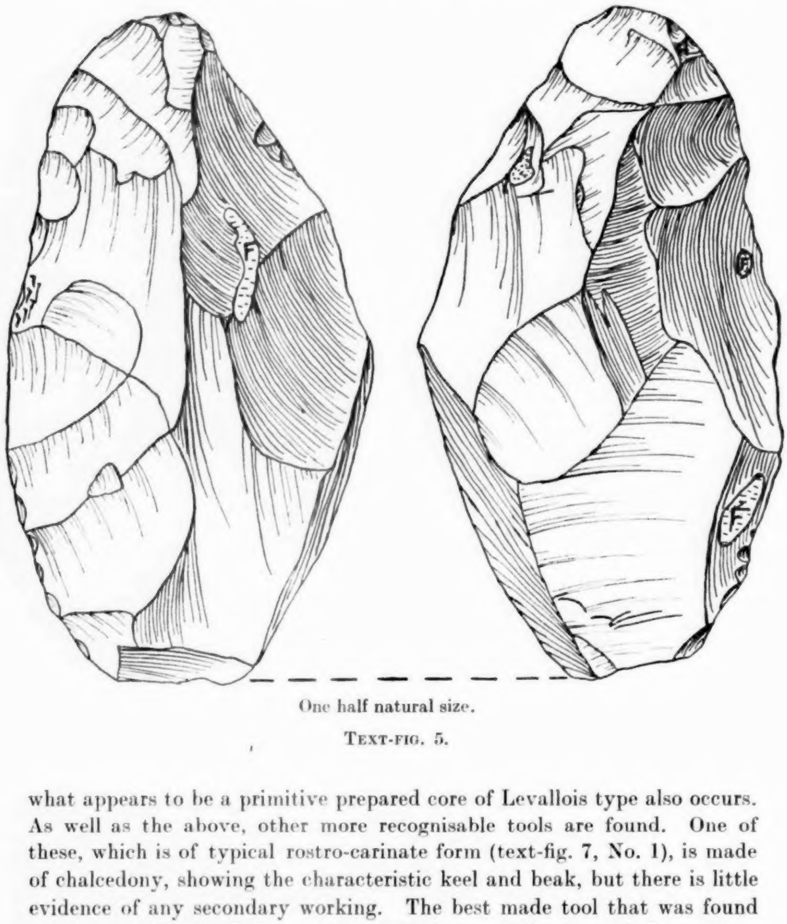



TEXT-FIG. 4.

most part within the rubble bed, while the others are found mainly on the surface of the deposit. One large nodule of chalcedony trimmed to form a roughly beaked tool exhibited a white patina, except where one side of the cutting edge has been entirely re-worked at a later date and shows the light brownish-green patina. This evidence indicates that the "culture" should be divided into at least two different stages.

The outstanding type of implement appears to be a nosed tool (text-fig. 6, Nos. 2, 4, 5) made from a chalcedony nodule, the working edge being formed by the intersection of a number of irregular flake scars

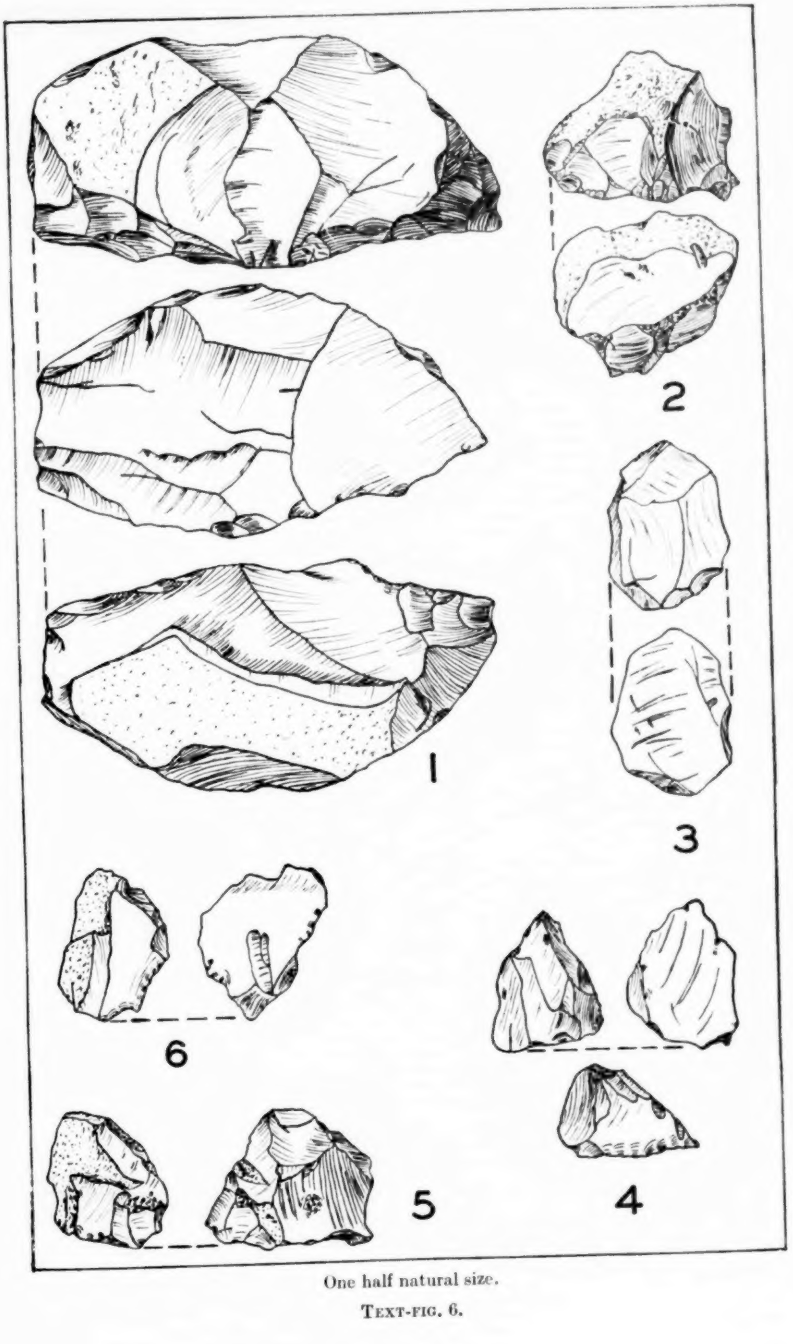
above with one large flake scar below. Out of twenty-one cores recovered, fourteen of them have been worked in this manner. Other core tools with a chopping edge formed by the intersection of a number of flake scars struck from the two sides of the artifact have been recovered, while



One half natural size.

TEXT-FIG. 5.

what appears to be a primitive prepared core of Levallois type also occurs. As well as the above, other more recognisable tools are found. One of these, which is of typical rostro-carinate form (text-fig. 7, No. 1), is made of chalcedony, showing the characteristic keel and beak, but there is little evidence of any secondary working. The best made tool that was found (text-fig. 6, No. 1), however, was picked up at the foot of the cutting, out of the talus composed of Kalahari sand and material from the rubble bed. The implement is a perfect example of the true rostro-carinate of quite an advanced form, and is made from a large flake of the pipe sand-

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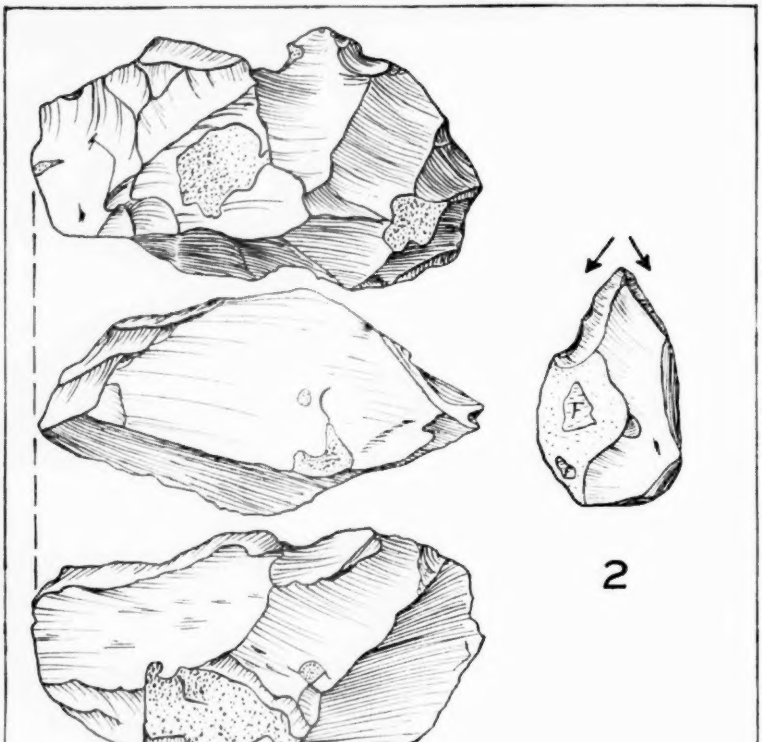
TEXT-FIG. 6.




One half natural size.

TEXT-FIG. 7.

stone stained a bright red colour, a modern chip showing the unpatinated white interior of the stone. It is entirely unrolled and shows no signs of weathering. It would appear, therefore, that this tool has been derived from the rubble bed, as, if long exposed to the air, this soft sandstone would quickly have weathered to an unrecognisable shape. Further search is being made in these cuttings and also in the cuttings north of Livingstone, since the discovery is important as showing the presence of man in the area at a much earlier date than was previously thought, unless of course the Kalahari sand overlying these sections is not of the age that is generally supposed. Until further evidence is forthcoming it would be unwise to base too much on this occurrence, but it is by no means improbable that the makers of tools of this Pre-Abbevillian * Culture, from which the Hand-axe Culture was gradually evolved, were living on this old land-surface at a period that is probably Lower Pleistocene. In the absence of pebbles this industry cannot be called a Pebble Culture.† Whether the assemblage constitutes the tools and waste flakes of a people practising an evolved form of Pebble Culture who have adapted to their use fragments and nodules of rock from the underlying beds, or whether it is an entirely separate contemporary culture, remains to be proved. In the Vaal River tools of rostroid form (Stellenbosch I) are not apparently found in earlier deposits than the earliest aggradation of the Younger Gravel. These are assigned to the first peak rainfall period of the First Wet Phase. No forms other than simple pebble tools are recorded from the surface of the Vaal Older Gravel under undisturbed Kalahari sand. It would seem, therefore, if one may presume to equate the carstone rubble bed of the Falls with the Older Gravel of the Vaal, that there was a considerable lapse of time before the influence of this culture made itself felt in the valley of the Vaal River.

During the period of aridity when the Kalahari sand was being deposited on the top of the old land surface, it is almost certain that man had retreated to less inclement areas and was not living in this vicinity; certainly no artifacts have been found that can be assigned to the period. The interval between this culture and the time when the African Pre-Abbevillian Culture appeared in the Vaal River Valley was probably also due to this Kalahari Arid Phase.

The onset of wetter conditions led to the erosion of the overlying sand, the development of the original Zambesi channel, and the deposition of leached river sand. No implements have as yet been found in this sand below the Older Falls Gravel. Rolled tools of rostroid form occur in the

* Formerly termed Pre-Chellean.

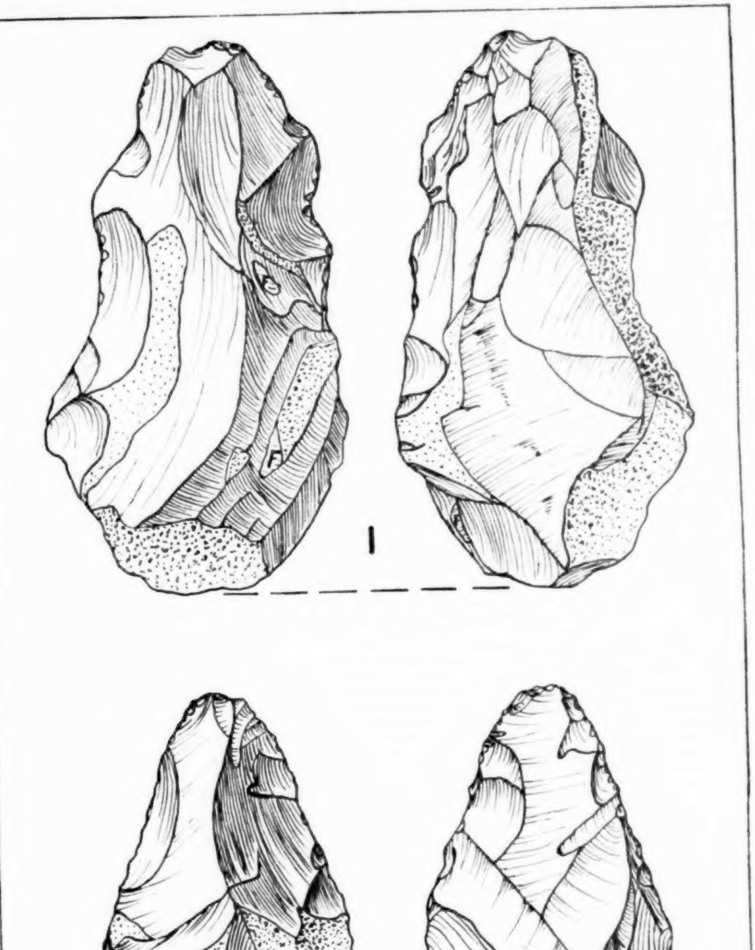
† A few river pebbles exhibiting human workmanship at one end have been found, but it is not yet possible to assign them to any particular climatic phase.

Older and Younger Falls Gravels, but as it was not possible to be absolutely certain that they are not merely unfinished specimens belonging to the African Acheulian, they could not be used as evidence of an Earlier Culture. It would seem, however, in view of the discovery of rostro-carinates *in situ* underlying the Kalahari sand, that some of these derived implements may well be tools of this Pre-Abbevillian Culture.

It may be convenient to note here that a very large percentage of the Older Stone Age tools found in this area are made from the local chalcedony which may be found ready to hand at the foot of the slopes of the Kalahari escarpment. The use of this flint-like rock, which is full of irregular cavities, led to the production of numerous roughly made tools. Where an unfaulty piece of material was used, however, tools of considerable delicacy could be produced. The danger of using typological evidence alone as a method of dating is thus easily seen, as an unfinished "block-out" of African Acheulian manufacture, showing typical Abbevillian technique, might erroneously be assigned to the African Abbevillian. For this reason only tools that have been found *in situ*, or in such circumstances and conditions as would render their attribution to a definite culture comparatively certain, have been used as dating-evidence. A number of finished hand-axes, exhibiting various degrees of rolling and with concretions of ferricrete adhering to them, have been found in the Younger Falls Gravel. As it is now practically certain that the ferricrete was laid down during one specific period, namely during the dry phase separating the Earlier and Later Wet Phases, it may be accepted with a considerable degree of probability that these implements have been derived from the Older Falls Gravel.

A few implements, all rolled and showing signs of use, have been found at the bottom of the Older Falls Gravel in the sections where this is of sufficient depth to allow of any stratigraphical distinction within the bed itself. Two of these tools are illustrated in text-fig. 7, No. 4, and text-fig. 8 No. 1. At present little more can be said of the African Abbevillian, until a site has been found yielding tools of this culture *in situ*, than that the men who made these tools were certainly living in the area during some period previous to the earliest aggradations of the Older Falls Gravel. The division between the African Abbevillian and the African Acheulian is purely arbitrary, and is based on a study of shape and technique. It is impracticable with the present evidence to divide the African Acheulian of the area into any more detailed divisions than Early, Middle, and Late. This is based mainly on technique and physical condition, but is also borne out by the stratigraphical evidence where available.

The paucity of the evidence by which we may definitely assign certain tools that have been recovered to the early African Acheulian is to be



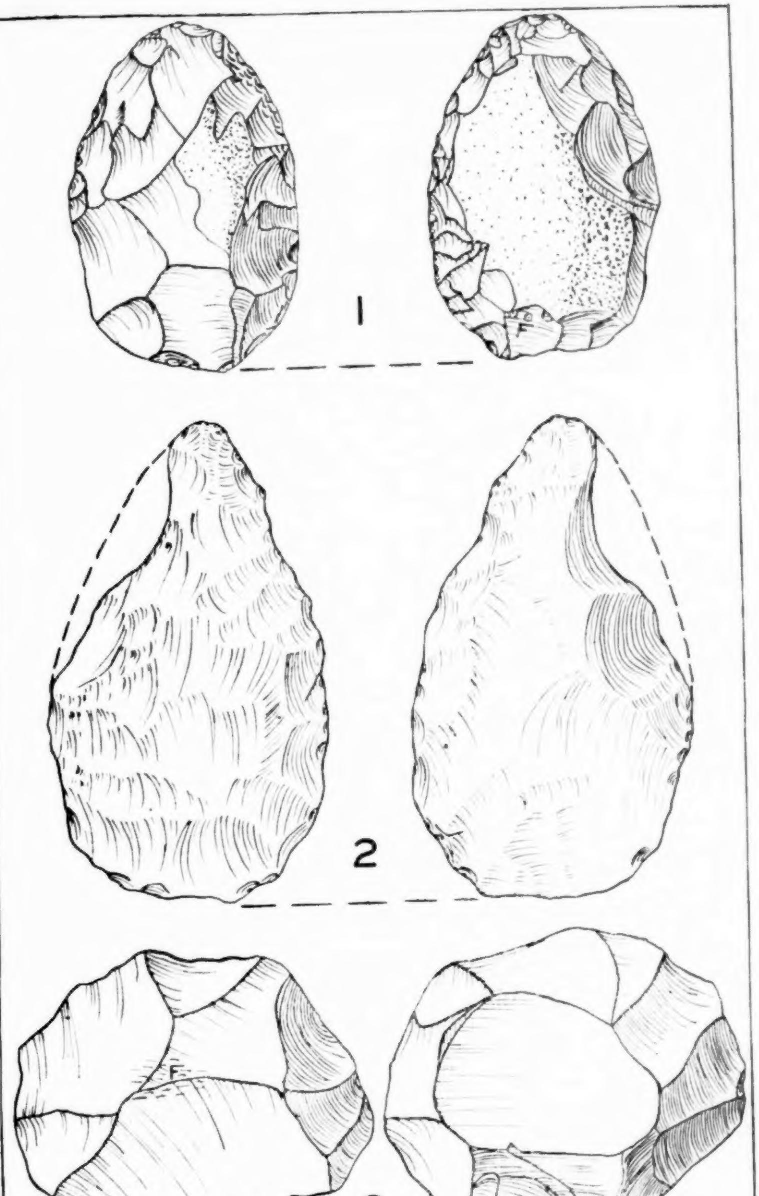

One half natural size.

TEXT-FIG. 8.

deprecated. Hand-axes of this stage are large and pear-shaped, and no cleavers have been found. The large *coup de poing* illustrated in text-fig. 4 was found in a small stream-bed that here cuts through the ferricrete, exposing this deposit in section. This tool shows signs of having been rolled previous to its inclusion in the ferricrete, and it exhibits typical Abbevillian technique, but the shape and relatively straight-cutting edge suggest that it be relegated to the earliest stage of the Acheulian. Text-fig. 5 is also probably of early Acheulian date: made of basalt, it was found resting on the top of the ferricrete horizon, beneath 3½ feet of Younger Falls Gravel II.

In dealing with the Middle Acheulian, the discovery of tools belonging to what are at present considered two separate phases of the culture in terrace gravel in the Maramba Valley, has materially increased our knowledge of this division. In what is probably the first stage two types of hand-axes are found—the one is long and pointed, giving a symmetrical biconvex section, while the other is a large, rather badly made, ovate. Smaller tools of the same shape also occur. Cleavers are of the large U-shaped variety made on side flakes. In what has been tentatively called the second stage the same types still occur, though they have become smaller and better made (text-fig. 9, No. 2)—these are for the most part unrolled, while the earlier ones are rolled. The cleavers show a parallelogram section and are made on side flakes. There is no evidence that points to the use of the Victoria West technique, but there is reason to believe that some kind of primitive "tortoise core" may exist. Flake tools that occur in some numbers exhibit an unfaceted inclined striking platform, often with prominent bulb and semi-cone of percussion.

The late African Acheulian, tools of which occur, rolled and unrolled, at the top of the Older Falls Gravel and in the ferricrete horizon, contains a variety of types. The artifacts are on the whole smaller and more neatly made, with a thinner cross-section—the most characteristic types of hand-axe found being pointed, ovate, cordiform and pear-shaped tools with a characteristically flat butt, suggesting that they were made from flakes, although all evidence of a flake surface has been trimmed away (text-fig. 8, No. 2, and text-fig. 9, No. 1). It is important to note the occurrence of tortoise cores (text-fig. 9, No. 3) and detached flakes with faceted right-angled striking platforms, in intimate association with these hand-axes. It was at first considered that these tortoise cores and flakes pointed to the presence of a contemporary Levallois Culture; but from a study of the technique employed in the flaking of their upper surface and from the conditions under which they were recovered—in the same deposit and showing the same degree of rolling as tools of the Upper African Acheulian—no justification was found for disassociating




One half natural size.

TEXT-FIG. 9.

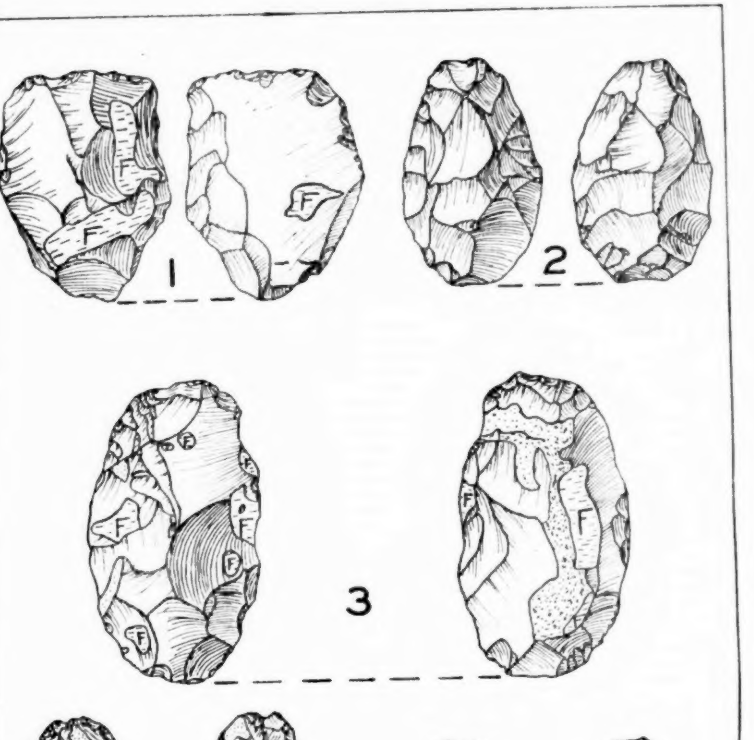
them from this culture. We have, therefore, during this period of declining rainfall at the end of the Earlier Wet Phase, a Hand-axe Culture practising two techniques—Levallois and Clacton.* Evidence for this is further established by Mr. Neville Jones' (1938) discoveries in the Bembesi Valley, at Gwelo, Hope Fountain, and elsewhere in Southern Rhodesia.

The writer is inclined to consider that this Levallois technique was gradually evolved within the Hand-axe Culture complex itself, and was not induced through contact with an outside culture. There is, in the Luangwa and tributary rivers, evidence of an early form of this culture, with artifacts made from quartzite river-pebbles, associated with a primitive Levallois technique. This would appear to be not unlike the Sangoan of Uganda, and it is thought that it was from some such culture as this that the Late African Acheulian Culture of Rhodesia was derived.

Apparently associated with the Hand-axe Culture are round balls of quartz that show signs of having been purposely battered into shape. These balls are usually quite round, and resemble the modern Bantu grinding balls used in this territory for grinding snuff. It is just possible that these balls have been naturally battered, but irregular lumps of quartz showing obvious signs of abrasion by river action are also found with them, and the characteristic battering is absent on these latter. These balls, invariably made of crystalline quartz, may conceivably represent the integral parts of an offensive weapon of the bolas variety.

The next culture, which would appear to have certain aspects in common with the Fauresmith of the Vaal River, is found unrolled in the same calcareous deposit from which the faunal remains came. It is also found elsewhere rolled and unrolled in the ferricrete horizon. This culture probably persisted, therefore, into the arid period separating the Earlier from the Later Wet Phase. Diminutive hand-axes (text-fig. 10, No. 2, and text-fig. 10, Nos. 3 and 6) and cleavers (text-fig. 10, No. 1) on flakes are found associated with cores such as that illustrated in text-fig. 7, No. 3, and with small tortoise cores. Flakes are of two kinds: those struck from the first type of core show inclined unfaceted striking platforms, while flakes with faceted platforms struck from tortoise cores also occur. Burins of the *bec de flute* (text-fig. 7, No. 2) and angle variety are also probably to be associated with this culture, but much more work is necessary in this area before a full description can be given. In the calcareous deposit in which the faunal remains were discovered, rolled Acheulian hand-axes are found associated with unrolled and slightly rolled flakes with prepared and unprepared striking platforms, small tortoise cores and cores similar to that illustrated in text-fig. 7, No. 3. This assemblage

* The names Clacton and Levallois are used here in the sense of two *techniques* only, and no reference is made to the *cultures* called by these names.




One half natural size.

TEXT-FIG. 10.

bears out the evidence from the conduit site that a culture similar to the Fauresmith was in existence at the very end of the Earlier Wet Phase.

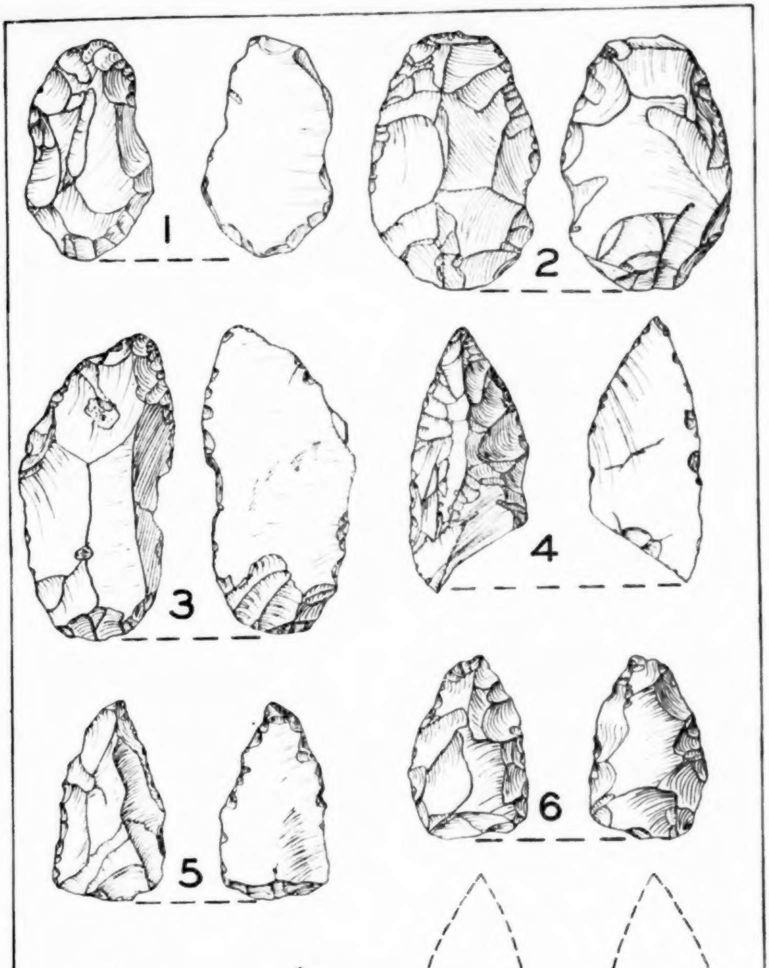
It is certain that the Hand-axe Culture did not persist into the next Wet Phase, but a totally different one then made its appearance and is first found, rolled, in the Younger Falls Gravel. For want of a better name this will be called Developed Levallois, as it approximates closely to Dr. L. S. B. Leakey's Developed Levallois Culture of Kenya. There is no evidence at present to suggest that this culture developed in the area, and it is more probable that its appearance is due to a migration from further north: the tool types found include side scrapers and points on Levallois flakes with secondary retouch (text-fig. 10, No. 5, and text-fig. 11, Nos. 1 and 5), and struck and unstruck tortoise cores.

In the Younger Falls Gravel II first occurs evidence of the Rhodesian Stillbay Culture. This can be divided into at least two stages, Lower and Upper.

The Lower Rhodesian Stillbay, which is always found, exhibiting various degrees of rolling, within the Younger Falls Gravel II, includes the following types of tools: diminutive tortoise cores and flakes with prepared platforms, struck from these; long flakes (text-fig. 11, No. 3), end and side scrapers and points showing pressure flaking and worked on one (text-fig. 11, No. 4) but occasionally on both sides (text-fig. 11, No. 6), often with the striking platform remaining (text-fig. 11, No. 2). Burins also occur, though many are probably only fortuitous.

The Upper Rhodesian Stillbay, of which a number of factory sites have been located, is found unrolled upon the surface of the Younger Falls Gravel II, where this is the most superficial deposit, for example on the surface of the terrace gravel south of the Silent Pool; it also occurs overlying re-deposited Kalahari sand on the old river-bed south of Gorge Four and elsewhere; it is found rolled in the lower terrace of leached river sand above the Falls. This culture is therefore tentatively assigned to the period preceding the Latest Wet Phase. Upper Rhodesian Stillbay types are more varied: pressure flaked points worked on one (text-fig. 11, No. 7) and both sides (text-fig. 11, No. 8), end, side (text-fig. 10, No. 7), and hollow scrapers, backed blades and crescents (text-fig. 10, No. 4), burins and round pressure flaked discs, which may possibly have been used as sling-stones. The factory debris consists of small tortoise cores, one other diminutive type of core, and flakes with faceted and unfaceted platforms.

This is the latest culture found in the area under consideration, but in and on the lower terrace of calcareous sand further up the river a few characteristic crescents of the Rhodesian Wilton have been found, unrolled, also with a factory debris which suggested its development from the Upper Rhodesian Stillbay.




One half natural size.

TEXT-FIG. 11.

It can be seen from the above attempted description of the Stone Age material that much is still problematical, and in the immediate area under consideration is likely to remain so. Owing to the shallowness of the actual Zambesi bed, the low drainage gradients and comparatively low relief of the surrounding country, true terraces are absent in the area, the result being normally a succession of thin deposits laid down one on top of the other. Although these deposits can be distinguished easily enough the one from the other, it is only in depressions within the underlying rock that any depth of deposit can be found. When division within the respective cultures rests upon stratigraphical evidence, the difficulty with which this may be determined will easily be seen. To gain a further picture resort must be had to the tributary rivers, the Maramba, Songwe, and Masue, where considerable thickness of deposits can be found giving a more exact stratigraphical distinction between the different "horizontal" divisions of a culture. The result of this supplementary research will be discussed later in a full report.

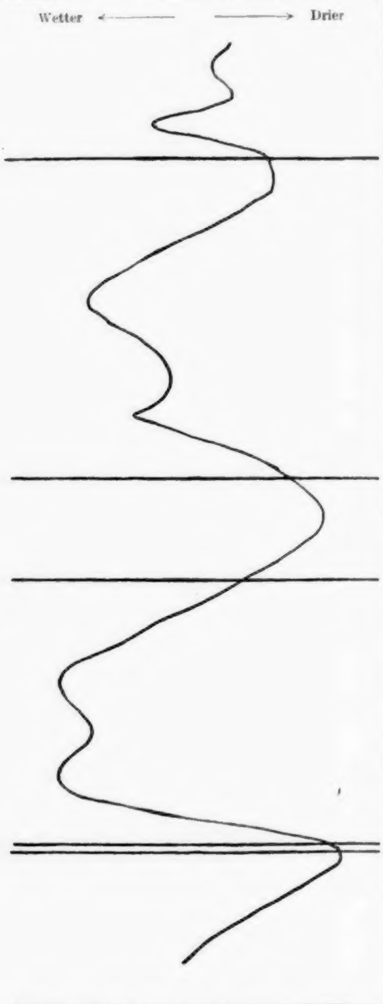
In so far as the stages of retrocession of the Falls affect the archaeology of the area under consideration, it may be said here that the contents of the gravel terrace below Gorge Three prove that the river cut its way back very much more quickly than had previously been thought. The distance between the Songwe River, 6 miles below the Falls, to the Third Gorge was almost certainly cut out during the Later Wet Phase when the Younger Falls Gravel was being deposited, thus leaving the old river-bed south of Gorge Four exposed to the deposition of wind re-distributed Kalahari sand on which unrolled tools of the Upper Rhodesian Stillbay are found. However, the full discussion of the evidence relating to the stages of retrocession of the Falls lies outside the immediate scope of this paper, and has therefore been deferred until the complete report on the archaeology of this area is published. [J. D. C.]

### Acknowledgments.

The authors wish to express their gratitude to Dr. L. H. Wells of the Department of Anatomy, University of the Witwatersrand, for the loan of casts of many described species of fossil elephant and for his courteous assistance, and also to Mr. Williams of the same Department for his kindness in preparing the casts of the specimens. The thankless task of preparing the illustrations of the stone implements was carried out by Mrs. Clark, to whom the authors are deeply grateful, and the excellent photographs they owe to Mr. W. Paff of the University of the Witwatersrand. They are also indebted to Professor C. van Riet Lowe, Director of the Bureau of Archaeology, for his assistance and kindness in communicating this paper on their behalf.

TABLE SHOWING PROVISIONAL CORRELATION OF CLIMATIC CHANGES, DEPOSITS, AND ASSOCIATED

Diagrammatic curve of climatic changes.




| Sequence. | Period. | Culture. |
|---|---|---|
| Humic Soil (Erosion to Present Contours) | Present Phase | Rhodesian Wilton (probably Stillbay) |
| Calcareous sand of Lower Terrace | Latest Dry Phase | |
| (Erosion of Lower Terrace) | Latest Wet Phase | |
| Wind re-distributed Kalahari Sand and White River Sand | Later Dry Phase | Upper Rhodesian Stillbay |
| Younger Falls Gravel II (? Flood Gravel) (Erosion of Younger Falls Gravel I, Older Falls Gravel and Ferricrete) | Later Wet Phase | Lower Rhodesian Stillbay (Ne lating traits from previous cul |
| Younger Falls Gravel I (Erosion of Ferricrete and Older Falls Gravel) | | Developed Lavallois (intrusive c |
| Production of Ferricrete Horizon | Earlier Dry Phase | Fauresmith (small hand axes faceted and unfaceted platfor |
| Calcareous pebbly sand with Fossil Remains<br>Older Falls Gravel with sand lenticles<br>(Erosion of white sand)<br>Deposition of white sand<br>(Erosion of basalt) | Earlier Wet Phase | African Acheulian (hand axes often on flakes; two flaking Levallois)<br>African Abbevillian (*coup-de-p* pebbles and large flakes from |
| Formation of Kalahari Sand | Kalahari Arid Period | |
| Formation of "carstone nodule bed" | | Pre-Abbevillian (rostro carinat nodules of chalcedony) |
| Deposition of "Pipe Sandstone" | Kalahari Wet Phase | |
| (Formation of chalcedony) | | |

*H. B. S. Cooke and J. D. Clark.*

T

ASSOCIATED CULTURES.

| Culture. |
| --- |
| Vilton (probably from Upper Rhodesian |
| sian Stillbay |
| esian Stillbay (Neanthropic culture assimi- s from previous culture) |
| avallois (intrusive culture) |
| (small hand axes and cleavers, flakes with l unfaceted platforms) |
| eulian (hand axes and cleavers, at the end, lakes; two flaking techniques—Clacton and |
| bevillian (coup-de-poing made from river l large flakes from chalcedony outcrops) |
| ian (rostro carinates and tools made from chalcedony) |

To face p. 317

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## EXPLANATION OF PLATES AND TEXT-FIGURES.

In text-figs. 4–11, "F" denotes concretions of ferricrete or ferruginous gravel.

### PLATE XII.

*Palaeoloxodon darti* Cooke.

Posterior portion of type left lower molar.

FIG. 1. Crown view.

FIG. 2. Outer lateral view.

### PLATE XIII.

*Palaeoloxodon darti* Cooke.

Type upper third left molar.

FIG. 1. Inner lateral view.

FIG. 2. Crown view.

TEXT-FIG. 1.—Sketch Map of the area, showing the chief features and sites.

TEXT-FIG. 2.—Generalised section exposed in the wall of the conduit leading water from above the Falls down to the Power Station.

TEXT-FIG. 3.—Section exposed in the trench dug at the south end of the Storm Drain to the east of the Power Station.

TEXT-FIG. 4.—Large rolled *coup de poing* made of chalcedony, found eroded from ferricrete horizon in an old stream bed due east of the Silent Pool.

TEXT-FIG. 5.—Large rolled *coup de poing* made of basalt, found resting on top of ferricrete in the conduit section.

TEXT-FIG. 6.

No. 1. Rostro-carinate made from a lump of the pipe sandstone, unrolled and unweathered, picked out of the talus at the foot of the Railway Cutting south of the Victoria Falls Station.

No. 2. "Nosed" core tool of chalcedony, unabraded, found *in situ* in Southern Railway Cutting.

No. 3. Chalcedony flake, unabraded, with primitively faceted butt, found *in situ* in Northern Railway Cutting.

No. 4. "Nosed" core of chalcedony, unabraded, showing signs of use as a tool, found *in situ* in Northern Railway Cutting.

No. 5. Core tool of chalcedony, unabraded, found *in situ* in Northern Railway Cutting.

No. 6. Small chalcedony flake, unabraded, showing signs of use along one edge, found *in situ* in the Southern Railway Cutting south of the Victoria Falls Station.

TEXT-FIG. 7.

No. 1. Unabraded rostro-carinate of chalcedony, found *in situ* within the carstone rubble bed, Northern Railway Cutting.

No. 2. Burin, *bec de flute*, from Younger Falls Gravel, Silent Pool.

No. 3. Rolled chalcedony core from Younger Falls Gravel, Conduit Section.

No. 4. Small rolled *coup de poing* made from a chalcedony pebble, found *in situ* at base of Older Falls Gravel in a section exposed at the Eastern Cataract.

TEXT-FIG. 8.

No. 1. Rolled hand-axe of chalcedony found at base of Younger Falls Gravel in Conduit Section.

No. 2. Unrolled hand-axe of chalcedony from under ferricrete horizon, Conduit Section.

TEXT-FIG. 9.

No. 1. Slightly rolled hand-axe of chalcedony from Younger Falls Gravel, about one mile above Eastern Cataract.

No. 2. Rolled hand-axe of chalcedony from Younger Falls Gravel, due east of the Silent Pool.

No. 3. Slightly rolled tortoise core of basalt from ferricrete horizon, Storm Drain Section.

TEXT-FIG. 10.

No. 1. Small cleaver of chalcedony, slightly rolled, from Younger Falls Gravel, Silent Pool.

No. 2. Small hand-axe, rolled, from Younger Falls Gravel, Silent Pool.

No. 3. Small hand-axe of chalcedony, slightly rolled, from ferricrete horizon, Storm Drain Section.

No. 4. Unrolled crescent of chalcedony, found in a factory site under a thin deposit of wind-blown sand just north of the Silent Pool.

No. 5. Rolled chalcedony flake with faceted butt, from Younger Falls Gravel, Conduit Section.

No. 6. Small rolled hand-axe of chalcedony, from Younger Falls Gravel, Silent Pool.

No. 7. Unrolled scraper of chalcedony, found on surface of Younger Falls Gravel at a site due east of the Silent Pool.

TEXT-FIG. 11.

No. 1. Rolled point of chalcedony, from Younger Falls Gravel I, Conduit Section.

No. 2. Slightly rolled flake of chalcedony, partly worked on both sides by pressure flaking, from Younger Falls Gravel at fifth gorge.

No. 3. Slightly rolled flake of chalcedony, showing pressure flaking, from Younger Falls Gravel at Silent Pool.

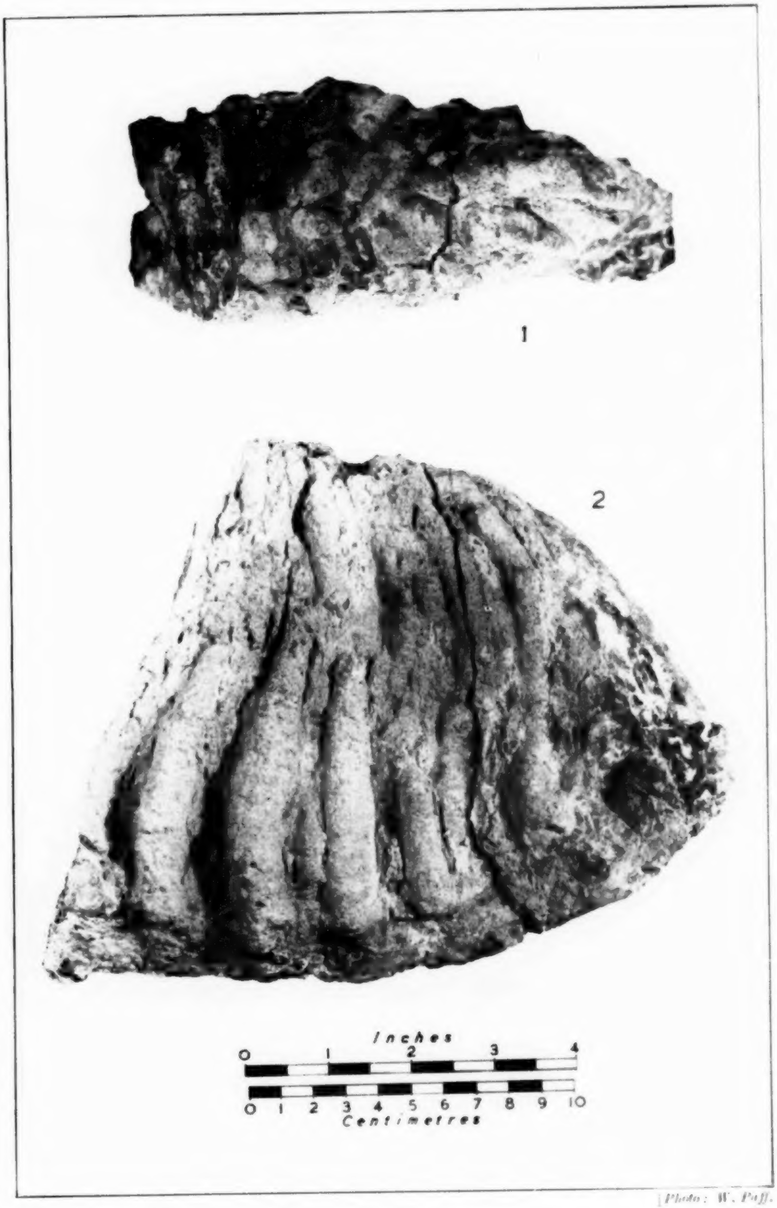
No. 4. Slightly rolled pressure flaked point from Younger Falls Gravel, Conduit Section.

No. 5. Rolled point of chalcedony, from Younger Falls Gravel at Silent Pool.

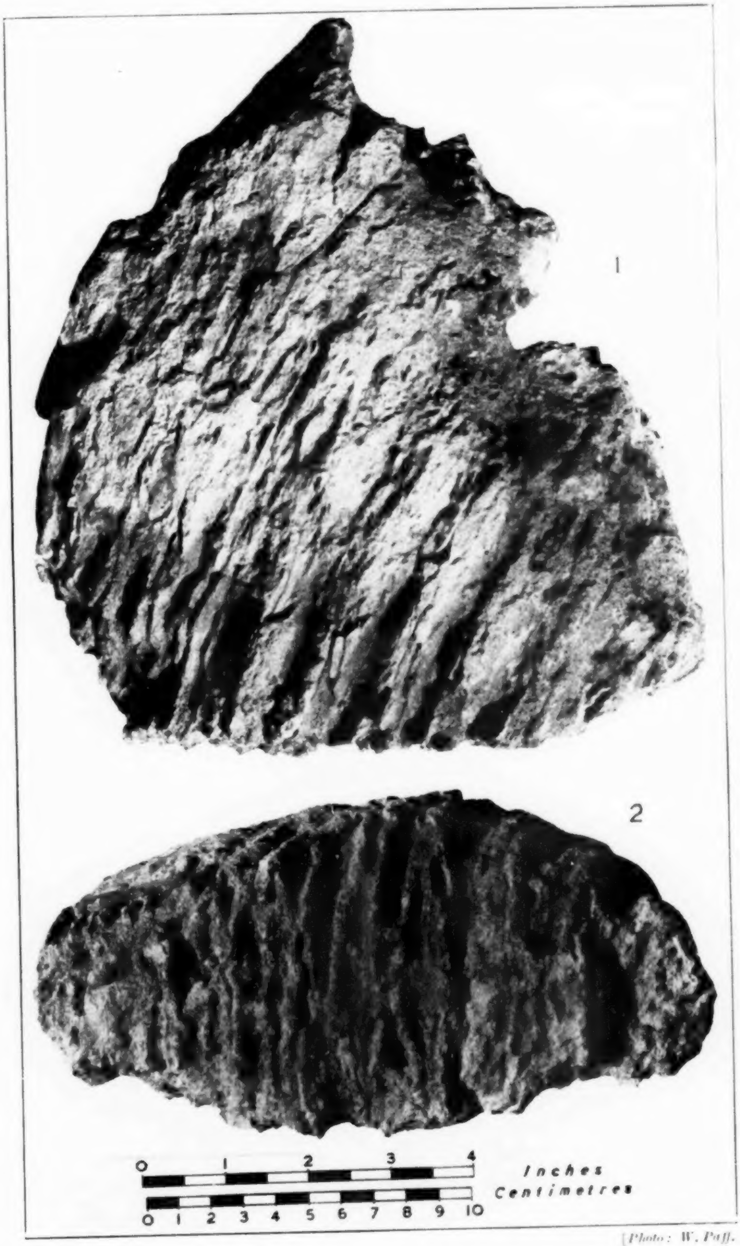
No. 6. Slightly rolled pressure flaked point of chalcedony, worked on both sides, from Younger Falls Gravel, Silent Pool.

No. 7. Unrolled pressure flaked point of chalcedony, worked on one side, found on the surface of Younger Falls Gravel at a site due east of the Silent Pool.

No. 8. Unrolled pressure flaked point, found on surface of Younger Falls Gravel at a site due east of the Silent Pool.




[Photo: W. Paff.




[Photo: W. Paff.

H. B. S. Cooke and J. D. Clark.

Neill & Co., Ltd.

# A PROJECTION METHOD OF MAPPING FROM AIR PHOTOGRAPHS.

By H. G. Fourcade.

(With Plate XIV and twenty-one Text-figures.)

(Read June 21, 1939.)

## I. Introductory.

An instrument already described in various publications under the name of *Stereogoniometer* * has been constructed for the determination of the relative tilts in space of pairs of photographs taken from the air without ground control, or of their absolute tilts given ground control. A mapping mechanism was also described in the first of the papers enumerated, but the cost of making the complicated parts with sufficient precision has hitherto prevented its realisation, although it is understood that a modified form is being made for the British Air Survey Committee,† and another for Canada. Meanwhile, it appeared that the construction of the maps from the coincidences of projected images of the photographs was an alternative possibility.

The projection of two photographs to combine stereoscopically on a screen was first effected by d'Almeida.‡ He used green and red light for projecting the pictures and corresponding filters for viewing them.

The idea of utilising this method for constructing maps from the coincidences of images when the photographs and lenses are disposed in the same relative positions the exposed plates and camera lens occupied in space at the times of exposure is due to Scheimpflug.§ The drawback of

* H. G. Fourcade, "A New Method of Aerial Surveying," Transactions of the Royal Society of S. Africa, vol. xiv, p. 1 (1926); *ibid.*, Second Paper, *loc. cit.*, vol. xvi, p. 1 (1928); *ibid.*, Third Paper, *loc. cit.*, vol. xviii, p. 237 (1929); Note on the Determination of the Verticals of a Plate Pair, *loc. cit.*, vol. xvii, p. 21 (1928); M. Hotine, The Fourcade Stereogoniometer, H.M. Stationery Office, 1930.

† Report of the Air Survey Committee, No. 2, 1935, p. 34, London, 1936; E. H. Thompson, An Automatic Plotting Machine for use with Air Photographs. Conference of Empire Survey Officers, 1935; Report of the Proceedings, p. 127, H.M. Stationery Office, London, 1936.

‡ I. Ch. d'Almeida, Bull. de la Société Française de Photographie, p. 290, Paris, 1858.

§ Th. Scheimpflug, Photogr. Korresp., 1898, 114–121.

this method is that, strictly, it can be applied only when the country to be mapped is flat and level. In other cases, if the lenses and photographs are raised or lowered to bring into coincidence pairs of corresponding points at other heights, the convergence of the images changes when they are brought again into focus. If the focus is not altered, the convergence remains the same, but the images become blurred and precision is lost. This effect may be minimised by reducing the aperture of the lenses, but remains considerable since sufficient light must be admitted to render the projections visible. Moreover, the scale of the projected image is determined by the focal length of the lenses, and can be varied between small limits only.

Various modifications of the method have been made by Gasser in Germany,* Nistri in Italy,† and Nelles in Canada, but in all of them the attempt is made to maintain equality of convergence of the rays in space and of the rays in the projection, with the result that every essential defect of the method remains.

The object of the new method, detailed in the present paper, is to provide means whereby both images, which may have been photographed at different heights, remain in sharp focus at all projection-levels, while their geometrical relations remain mathematically accurate, and, at the same time, a wide range of scales for the constructed maps is made available.

In contradistinction with the methods hitherto followed, in which the photographs are set in positions corresponding to those they occupied in space, the present method utilises this necessary knowledge of the positions to rectify each picture to a horizontal plane and constant principal distance. The rectified pictures are then projected, in an instrument called a *Stereo-projector*, to a common plane and any required scale, within limits.

The prior determination of the plumb point is best effected in a stereogoniometer, from known spot heights, or from the preceding adjusted photographs of a strip. An instrument for the purpose need only take lantern-plate reductions of the original negatives, and would be small and compact. These unrectified reductions may be made in the rectifying camera with the stages set at the zeros of their inclinations. When a stereogoniometer is not available the determination can be made with the stereoprojector itself, using the same unrectified reductions, as will be further shown in the sequel, but the procedure necessarily becomes more laborious.

Taking advantage of the circumstance that the tilts of the photographs rarely exceed 2°, the subsequent rectification may be effected in a comparatively simple form of camera and with practically no computations,

* Gasser, D.R.P. 306384, April 1915.

† Nistri, Brit. Pat. 219915, Feb. 1923.

since, for small tilts, as was shown by the author in a previous paper,* the variation in the camera settings becomes, with sufficient approximation, linear in relation to tilts, and may be read directly from a small table computed once for all for a particular rectifying camera. It was also shown that, in the result, the errors due to small differences in the focal length of the air lenses, to distortion from the pressure plate, and to average contraction of the film, may be eliminated automatically.

On account of the comparative coarseness of grain of a fast film, motion of the aeroplane, vibration, and other causes, all the detail that is visible on an aerial negative $7 \times 7$ in., or $5 \times 5$ in., can be transferred, without loss of definition, to a slow plate of fine grain, such as a lantern-plate $3\frac{1}{4} \times 3\frac{1}{4}$ in., by projection printing in the rectifying camera. The direct use of larger films would not increase the accuracy sensibly, but only increase the weight and unwieldiness of any instrument made to take them, in proportion to the cube of the dimensions, besides multiplying its cost.

## II. Theory of the Instrument.

In fig. 1, $L$ and $R$ represent a pair of rectified copies, with a common principal distance $p$, of air photographs taken at heights $h_a$ and $h_b$ above a datum plane $MN$.

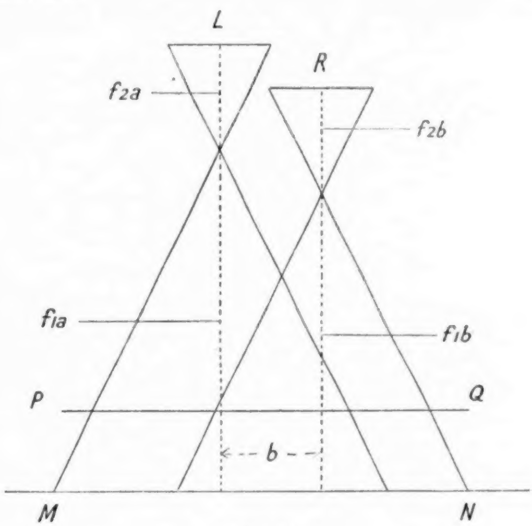



Fig. 1.

* Empire Survey Journal, Jan. 1936.

For reprojecting, at the map scale $s$, the images on $L$ and $R$ of points on the datum plane $MN$, the magnifications must be $\frac{sh_a}{p}$ and $\frac{sh_b}{p}$, where $sh_a$ and $sh_b$ are the heights—reduced to the map scale $s$, of the two air stations. Therefore *

$$\frac{f_{1a}}{f_{2a}}=\frac{sh_a}{p} \quad \text{and} \quad \frac{f_{1b}}{f_{2b}}=\frac{sh_b}{p},$$

or, if $f$ is the focal length of both projection lenses,

$$f_{1a}=f\left(1+\frac{f_{1a}}{f_{2a}}\right)=f\left(1+\frac{sh_a}{p}\right),$$

$$f_{1b}=f\left(1+\frac{sh_b}{p}\right).$$

For the reprojection, on the same scale, of the images of points on another plane $PQ$ at a height $c$ above $MN$ we have again

$$f'_{1a}=f\left(1+\frac{s(h_a-c)}{p}\right),$$

$$f'_{1b}=f\left(1+\frac{s(h_b-c)}{p}\right),$$

and

$$f_{1a}-f'_{1a}=f\frac{s}{p}c,$$

$$f_{1b}-f'_{1b}=f\frac{s}{p}c,$$

so that at successive levels $c$, $2c$, $3c$, etc., to trace contours to scale, it will be sufficient to raise the plane $MN$ by $f\frac{s}{p}c$, $2f\frac{s}{p}c$, etc., or, conversely, to lower the lens assembly equally by the same amount, provided the plates $L$ and $R$ are automatically, or otherwise, kept in conjugate focus with the plane of the projection. By means of a hand-wheel actuating, through suitable mechanism, the lens system vertically, the tracing point may be kept in apparent contact with any detail and its plan traced irrespective of variation in height.

The vertical disposition of the projecting systems shown in fig. 1 would have the disadvantage of preventing their close approach to give a sufficiently small instrumental base, and the projections would be mirror images of the topography. For these reasons the modification shown in

* Trans. Roy. Soc. S. Afr., vol. 14, p. 75 (1926).

fig. 2, in which the optical axes are broken at right angles, is preferable, but the theory remains identical with that of fig. 1. The plates $L$ and $R$, the projection lenses and the reflectors are carried on a horizontal bridge which may be moved vertically, by means of a pair of linked screws

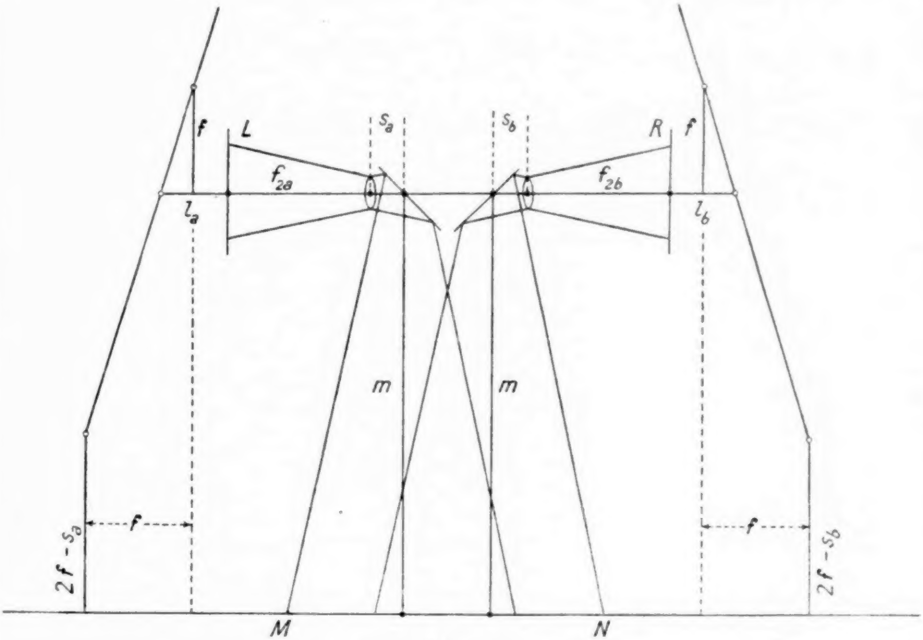



FIG. 2.

actuated by a hand-wheel, from the surface plate $MN$ on which the projections are made. By setting $s_a+m=f_{1a}$ and $s_b+m=f_{1b}$, the lenses, mirrors, and plate centres may be kept at one height, that is on a single slide of the bridge, the difference between $f_{1a}$ and $f_{1b}$, which is constant for one pair of plates, being taken up by either $s_a$ or $s_b$. The points where the optical axes intersect the mirrors are separated by the length of the base on the scale used.

The plates are constrained to remain in conjugate focus with the surface plate by means of straight rules against which a point, in practice a roller, of each plate carriage is kept pressed. Each rule is centred at a point $2f-s$ above the level of the surface plate and is kept in contact with a fixed point, or roller, at a height $f$ above the level of the carriage roller and

distant, horizontally, also $f$ from the lower pivot. Each auto-focussing system is at any arbitrary distance on its side of the instrument and actuates the plate carriage by means of a distance piece $l_a$ or $l_b$, the length of which remains constant after each setting of a pair of plates.

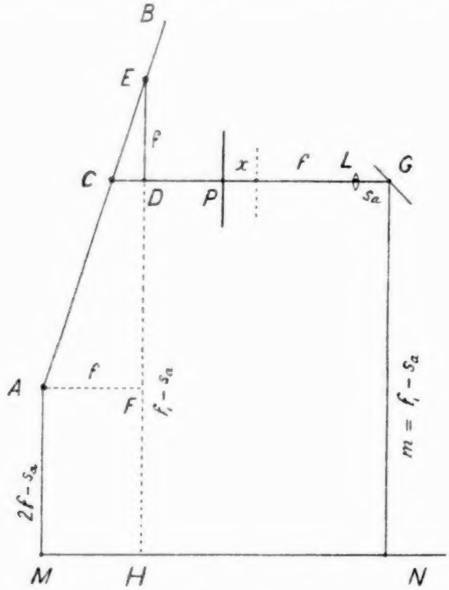



Fig. 3.

In fig. 3, $AB$ is the rule, centred at $A$ and touching a point $C$ of the plate carriage and a point $E$ fixed on the bridge at a height $f$ above $C$. Put $f_2 = f + x$. From the lens equation

$$\frac{1}{f_2} = \frac{1}{f} - \frac{1}{f_1} = \frac{f_1 - f}{ff_1}$$

we get

$$x = f_2 - f = \frac{ff_1}{f_1 - f} - f = \frac{f^2}{f_1 - f}.$$

We have also, from the similar triangles $CDE$ and $AFE$,

$$CD = \frac{f_2}{EF}.$$

The condition that will make $CD = x$ is that $EF = f_1 - f$ and it is satisfied if $AM$ is made $2f - s_a$, since $EF = DH + ED - AM$. $CD$ being equal to $x$,

$C$ and $D$ will move equally if connected by a distance piece of fixed length and the plate will remain in the conjugate focus of $MN$ when the bridge carrying the assemblage $ECDPLG$ is moved vertically in order to vary $f_1$.

It is not convenient to have, actually, $P$, $L$, and $G$ on the same level as $CD$. They may be placed at some lower level if $A$ is fixed higher by the same amount, as this will maintain the appropriate length of $CD$. They can also be offset horizontally without disturbing the relations.

The scale of the mapping is determined by the separation of the points $G$ of the two mirrors. This separation may be varied by altering the length of $CP$ without changing the relative positions of $P$, $L$, and $G$. When the two air stations are not at the same height, the projected images will not be in correspondence. By turning by equal readings the micrometer moving $A$ vertically and the micrometer separating horizontally $L$ from $G$, until correspondence is restored, the projection centre for the station will have been set at its correct height relatively to that for the other station. The base is then set back to its original length.

Once the instrument has been adjusted for any one pair of plates, or rather one pair of glass scales, the zeros of the instrument scales remain unchanged for any other pair of plates. The range of motion of the settings is under 4 in., so that they can be made, with engineer's micrometer gauges and interposed standard rods, to 0·01 mm. After the base setting has been made, the two lenses and their mirror remain fixed on the bridge during the whole of the mapping from one pair. The focussing mechanism consisting as it does of a single straight rule and three rollers in contact with the rule is extremely simple and may be made very accurate, ball-bearing rollers being procurable, commercially, accurate to 0·0002 in., also rules and surface plates to a similar order of accuracy, all at moderate prices.

## III. Description of Stereoprojector.

The instrument (Plate XIV) of which fig. 4 is a diagram consists essentially of a main bed supporting two pillars on which are guiding surfaces constraining the motion of a bridge across them. The bridge is moved vertically by means of a pair of coupled screws acting near the pillars. On the bridge are set the lens and mirror systems and a pair of travelling carriages supporting the plate stages. The motion of the carriages is regulated by the autofocussing rules hinged to the pillars and interposed distance bars.

*Base.*—The cast-iron bed and its stand are levelled by means of four stout screws resting on shoes with three V-grooves and a plane. Deep flanges provide sufficient longitudinal and lateral rigidity, but a small amount of torsional elasticity is purposely retained by leaving large openings in the bed top.

*Pillars.*—The pillars are made of special steel of cruciform section, departing but slightly from a T-section. They are attached to machined seatings on the base by screws opposing each separate contact. The

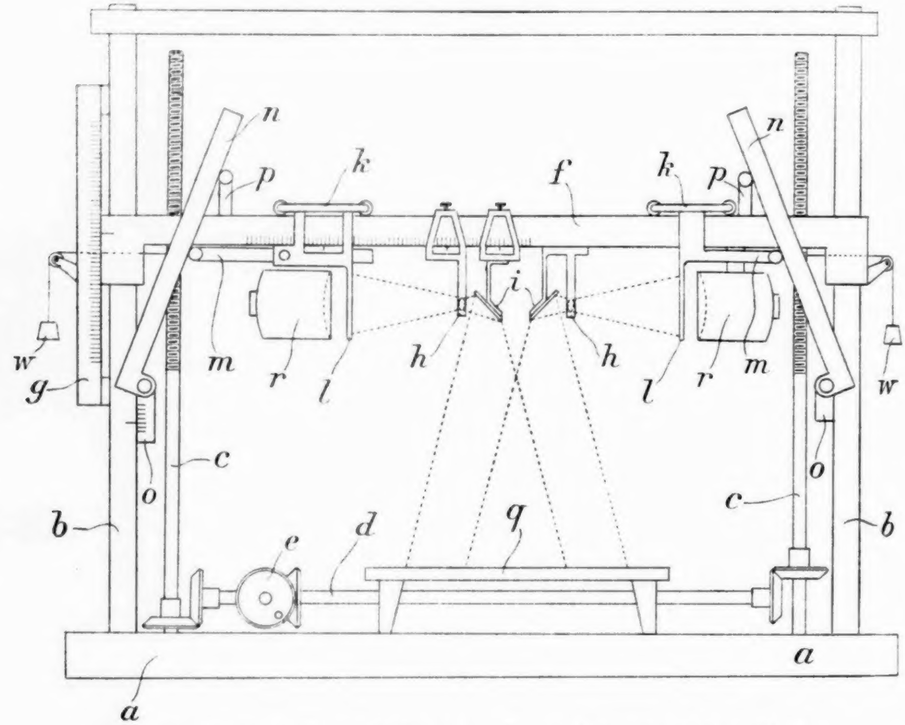



FIG. 4.—*a*, base; *b*, pillars; *c*, leading screws; *d*, cross shaft; *e*, hand wheel; *f*, bridge; *g*, indicating height scale; *h*, lenses; *i*, reflectors; *k*, carriages of plate stages *l*; *m*, distance bars; *n*, autofocussing rules; *o*, brackets of lower rollers; *p*, brackets of upper rollers; *q*, projection table; *r*, lanterns; *w*, weights driving carriage *k*.

pillar to the left is machined and scraped on its front and inner edges, and the pillar to the right on its front edge only. The seatings of the pillars are scraped to make the front guiding surfaces lie nearly in one plane. The very small residual discrepancy is readily corrected when levelling the machine. The provision of four foot-screws and the slight torsional elasticity left in the bed allow of the front guiding surface of each pillar to be made vertical independently, without interference with the vertical setting of the side guiding surface of the left pillar. When the

foot-screws have been clamped the bed-pillar assembly is quite firm, and appears to remain in good adjustment for months together. Such an arrangement is far more reliable than would be separate adjustments on the bed for parallelism of the pillars.

*Bridge.*—The bridge consists of a pair of rails, the back one a rectangular rule, and the front one of cruciform section, both attached to head blocks machined out of solid steel. In the heads are formed the bearings sliding over the guiding surfaces of the pillars, and they carry, for the reception of the leading screws, bronze nuts in conical seatings with set screws, for turning and setting when adjusting the rails of the bridge perpendicular to the inner guiding surface of the left pillar. The rails are assembled to the heads on an accurate surface plate, leaving the top surfaces of the rails the thickness of a sheet of paper above the surface of the heads in order that the further scraping of the rail assembly to a true plane may be done over the surface plate without interference from the heads. Opposing springs of which the pressure can be regulated ensure proper contact of the bearing surfaces of the bridge with the guiding surfaces of the pillars.

*Leading Screws and Micrometer.*—The leading screws have a pitch of 2 mm. and a diameter of 0·75 in. Their lower ends are fitted with Hoffmann thrust bearings WZ 9/16 with spherical seatings, the seating rings of which are sunk into the top surface of the bed of the machine. The two screws are constrained, by a cross-shaft and bevel gears, to turn equally, the motion being imparted by a hand-wheel connected with the gears.

The use of a spherical seating and ball-bearings is found to eliminate measurable periodic error while reducing the friction and wear to which a plain thrust bearing would be liable. It also limits, to a negligible cosine error, the effect of a small want of parallelism between the axis of the screw and the vertical guiding surfaces of the pillars.

The micrometer on the shaft of the left-hand leading screw has a double drum geared, in a well-known manner, by means of wheels with 49 and 50 teeth and a small pinion meshing both to a ratio of 1 in 50. One drum records whole turns up to 100, and the other hundredths of a millimetre.

*Offsetting of Projection System.*—The plate-stages, lenses, reflectors, and lighting lanterns, are disposed below the bridge and offset to the front of it, so that the horizontal portion of the optical axis remains clear of the vertical pillars. The weight of the overhanging parts is then relieved by adjustable spiral springs suspended from auxiliary carriers running on a rail moving with the bridge. The total weight of this rail and of the overhanging parts is then balanced by counterweights hung from chains running over pulleys attached to the top cross-bar of the machine, so that the bridge bears only the weight of the parts directly on it, and so distributed

that the pressure on each of the guiding surfaces is approximately the same.

*Lens and Mirror Assembly.*—The lenses are carried by slides on the bridge, and the mirrors by brackets attached to the lens-holders. Both mirrors are adjustable in their frames by means of three small screws after the manner of sextant mirrors. The distance of the left mirror from the lens can be varied by means of a slide operated by a micrometer head. That of the right mirror from the corresponding lens remains constant. The right slide of the bridge may be moved back 25, 50, or 75 mm. by interposing standard rods between stops, and the left slide moved up to 25 mm. by a micrometer head working against a stop. The least separation between the points where the optical axis meets the mirrors being 68·59 mm. in the first model, the base-line of the projection may be varied from 69 to 169 mm., and the scale of the map proportionately. The lenses are adjustable in collimation, by opposing screws, in the manner of the diaphragm of a theodolite.

*Carriage and Plate-Stage.*—The plate-stage is borne by a carriage running over the rails of the bridge on 5 ball-bearing rollers, the rims of which are slightly rounded to a radius of 3 in. in cross section. The rollers are mounted on eccentric pins, making the carriage universally adjustable to any position within a range of 1 mm. sufficient to correct the effect of cumulative errors in the workmanship of parts. A cross-beam of angle steel is connected to the carriage by an adjustable plate flexible near one edge, and from the beam depends the bed plate of the stage. The stage rotates and is filled with four adjustable slotted stops, in one plane, against which the diapositive is laid, and next set in register with the slitted stops by turning three screws opposed by springs. It is then secured to the stops by clamps.

The rotation of the stage is controlled by a clamp and slow-motion screw. A sine micrometer described below acts as a slow-motion screw.

From each carriage distance bars slide out. On the right the bar can be set back 25, 50 or 75 mm. by interposing standard rods between stops. One set of standards is sufficient for setting both the lens slide and the distance bar, because what is taken from the one is added to the other, the turn being always 75 mm. On the left carriage what is added to the base by means of the micrometer head on the left lens slide is taken off similarly from the distance bar by a second micrometer head acting against a stop on the bar. The front ends of both bars carry ball-bearing rollers, neither of them adjustable.

*Autofocussing System.*—The end roller of each distance bar is kept in contact with the corresponding straight rule by a small weighted cord and pulley. Each rule is pivoted on a roller securely fixed tangent to the

base of the rule, and these bearings are carried by brackets attached to the vertical pillars. Each roller pivot is adjustable on its bracket both laterally and vertically, but only the left bracket has a micrometer head measuring the vertical displacement of the pivot. The bridge carries at each end a bracket supporting a roller, adjustable in height, which is set at a vertical distance $f$ above the roller of the distance bar. The bottom roller pivot is set at a horizontal distance also $f$ from the top roller. The rule is kept in contact with the top roller by a spring connected to the frame of the machine. The middle roller being pressed against the rule and the bottom roller tangent to it by construction, all three rollers automatically remain in a straight line.

*Projection Table.*—This is formed by a plane cast-iron plate $18 \times 12$ in. and about $\frac{3}{4}$ in. thick, with four levelling screws, resting three of them in V-grooves and the fourth on a plane.

*Drawing Table.*—A map may be drawn directly on a sheet of paper laid on the projection table, but it is better for some purposes to use a separate table on which a pencil moves conformably with the mark on a target resting on the projection table. A very frictionless way of obtaining this correspondence is to use a cross-arm fitted with pairs of ball-bearing rollers set at right angles to each other, resting on a cylindrical rod fixed parallel to the top edge of the projection table, and carrying on its upper pairs of rollers a second cylindrical rod at right angles to the first. At one end of this rod is the target and at the other the pencil. The cross-arm moves laterally on the bottom longitudinal rod and the top rod transversally.

*Lighting.*—The lighting is effected by means of an ordinary type of lantern with condenser lenses and a reflector. The reflector consists of a biconvex lens silvered on the back, the combination acting as a concave mirror of radius a little less than half the radius of the lens surfaces. Red and green-blue filters may be inserted in front of the condenser lenses, and the picture viewed through a pair of spectacles fitted with glasses of the corresponding colours.

*Floating Marks.*—A single mark cannot be given any apparent depth and is not very effective for bringing points into correspondence. Better results were obtained from separating the two images of a point by a constant distance instead of setting them in coincidence. The constant distance is determined by the separation of a pair of marks which may be designed to appear in relief when recombined stereoscopically by viewing them through a pair of lenses of low power (Plate XIV). This method has the advantage of allowing the use of white light for the projections with great gain in illumination, besides which the two pictures remain of fairly equal intensity. This is not the case when red and blue-green lights are used, the visual intensity of the first being much the higher of the two.

The overlapping of the pair of pictures on the receiving target is then prevented by interposing an opaque strip held horizontally a few inches above. The position and width of this strip, which is borne by an arm on the target, can be altered at a touch when working over different portions of the picture. "Polaroid" filters were also tried, but their use is attended by marked loss of light without any important compensating advantages.

Another type of target in which the images, projected on a focussing screen of fine grain, are viewed reflected from under by a mirror which corrects the inversion was also experimented with. The picture is then seen normally, but its definition is impaired. Provision is, however, made in the instrument for the substitution of a screen target if preferred.

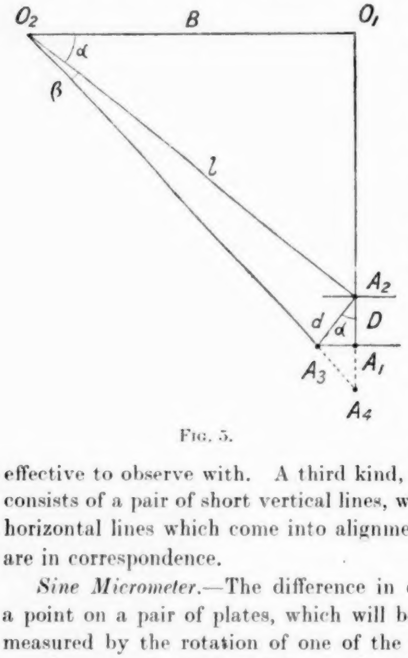



Fig. 5.

The target has several kinds of floating marks to choose from. A good mark appears as a **V** standing on its point. Another is formed by a pair of pinholes about 0·2 mm. in diameter which can be made to appear as a black dot, or, by transmitted light, as a conspicuous luminous point, particularly effective to observe with. A third kind, used for correspondence settings, consists of a pair of short vertical lines, which combine, flanked by thinner horizontal lines which come into alignment only when the points sighted are in correspondence.

*Sine Micrometer.*—The difference in correspondence of the images of a point on a pair of plates, which will be termed their *disparity*, may be measured by the rotation of one of the plates required to restore correspondence in the projected image the rotation of which is equal to that of the plate.

In the figure, $A_2$, on plate $O_2$, is brought into correspondence with $A_1$, on the $y$-axis of $O_1$, first, by bringing $A_2$ to the $y$-axis of $O$, through changing the magnification of the pair of pictures, then by rotating plate $O_2$ through an angle $\beta$ until $A_2$ is at $A_3$ on the parallel of $A_1$. If the magnification is again changed until $A_1$ is at $A_4$, along the $x$-axis of $O_1$, then $A_3$ will also be at $A_4$ since $O_1A_4/O_1A_1$, giving the change in magnification of the picture from $O_1$, is equal to $O_2A_4/O_2A_3$, giving the change in magnification of the picture from $O_1$.

The disparity of $A_1$ and $A_2$ is $D$. Angle $\beta$ being small, we have:

$$D = d \cos \alpha,$$
$$d = l \tan \beta,$$
$$l = B / \cos \alpha,$$

whence

$$D = B \tan \beta,$$

which is independent of $\alpha$.

The result may be extended to points not on the $y$-axis, in which case $D$ takes the form $D = X \tan \beta$. But for the determination of tilts, points on the $y$-axis alone need to be considered.

The $Z$ co-ordinate of the point $A$ must always be read, on the height screw, after $A_2$ has been brought to the $y$-axis of $A_1$, but before rotating plate $O_2$ to bring $A_2$ and $A_1$ into correspondence, and changing the magnification to make $A_3$ and $A_1$ coincide. Otherwise the stereoscopic difference would be in error by $A_3A_1$, and the reading of $Z$ proportionately.

For measuring the rotations $\beta$, each plate circle is fitted with a *sine micrometer* giving directly the sines of the angles of rotation, in parts of the

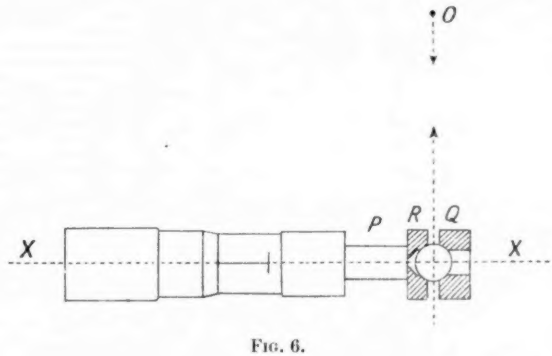



Fig. 6.

radius. The sine micrometer (fig. 6) consists of a micrometer head acting as a tangent screw to the circle. The spindle $P$ has a linear motion along the axis $XX$, while the part $Q$ has a rotation about an axis perpendicular to the plane of the paper at $O$. The part $Q$ seats a steel ball, and between the spindle $P$ and the ball is interposed a washer $R$ seated on the ball. The several parts are clipped together by a spiral spring at one side. The end of the spindle of a modern micrometer is lapped accurately square to its axis, and if the working face of the washer is also lapped plane, the small lateral motion is restricted to the sliding of surfaces, which can be kept lubricated, and wear rendered negligible. For the particular purpose,

this arrangement is better than any of the three described at p. 626, vol. iii, of the Dictionary of Applied Physics, in which there are point contacts which are also rubbing contacts.

The three faces of an indentation made in a surface by the corner of a cube are, when equal, inclined at an angle $a$, given by $\sin a = \sqrt{\tfrac{1}{3}}$, to the normal to the surface. To substitute small bearings for the three point-contacts of a ball resting in a trihedral hole, bore a conical hole with a countersink of angle nearest to $2a = 70° \; 30'$. File off three segments, leaving three small arcs of contact. Then with a spare ball and fine abrasive rub the seat until the contacts develop a sufficient surface.

The zero of the micrometer is the reading at which the radius from $O$ to the centre of the ball is at right angles to $XX$. The radius being made 100 mm. the readings of the micrometer give directly the natural sines of the angles of rotation.

The approximation of the method may be deduced. Actually $d$ is the chord of an arc of radius $l_2$ and we have

$$d = 2l_2 \sin \frac{\beta}{2},$$

$$D = d \cos\left(a + \frac{\beta}{2}\right),$$

whence

$$D = B \sin \beta \left(1 - \frac{\tan a \sin \beta}{2}\right).$$

When measuring disparities $B$ is best set at 100 mm. If $n$ is then the reading of the micrometer,

$$D = n\left(1 - \frac{y}{100} \cdot \frac{n}{200}\right).$$

The correction to $n$ will usually be less than the error of measurement. For $y = 100$ mm. when $l_1$ is also 100 mm. The correction $c$ may be taken at sight from a small table covering the usual range of $n$. As examples for $n = 1$ mm., $c = -0{\cdot}005$ mm. for $n = 2{\cdot}0$ mm., $c = -0{\cdot}020$ mm. for $n = 3$ mm., $c = -0{\cdot}045$ mm. For other values of $y$ multiply the correction by $y/100$.

## IV. Adjustments and Determination of Constants.

The appliances used for these purposes were levelling squares (Cooke, Troughton & Simms and P. Roche), parallels (Starrett), an inside micrometer with stand (Brown & Sharpe), indicator gauges on stands (Zeiss and P. Roche) reading to 0·01 mm., ordinary micrometer gauges (Brown & Sharpe

and Moore & Wright), graticule microscopes (Cooke, Troughton & Simms), precision squares (Brown & Sharpe and Moore & Wright), copies of astronomical réseau plates (P. Gautier), and a template serving to locate similarly the reference marks and the stops of all the related instruments. All the adjustments, except the first, are permanent maker's adjustments, which, being securely locked, need not be repeated unless the instrument has been transported, and suffered in consequence.

The instrument having been erected on a concrete floor with its footscrews resting in shoes supplied:

1. By means of the levelling square and the footscrews, set both guiding surfaces of the left pillar vertical. Next set the front guiding surface of the right pillar also vertical, using the footscrews on the right only. The seats of the pillars have been lapped, in construction, to render the front guiding surfaces of both pillars very nearly parallel, and enough torsional elasticity has been purposely left in the base to allow of the completion of accurate parallelism by very slight adjustment of the pair of footscrews. Clamp all four screws.

2. Set the bridge horizontal with parallel blocks laid across, and the levelling square, by turning one of the nuts with the clamp provided. Secure with the setscrews.

3. Set the top surfaces of the distance bars of the carriage, after clamping them, parallel to the bridge, as shown by an indicator gauge supported across, by turning the relative eccentric rollers. Lock these.

4. Level surface plate.

5. Remove circles and set their bed plates vertical (as indicated by a square put on the surface plate) by means of the flexibly hinged plates on the carriages.

6. Set the bed plates perpendicular to the front rail of the bridge, with the help of a rule clamped perpendicular to the bridge, a square based on the surface plate, and the inside micrometer gauge.

7. Replacing the circles, set their centres at equal heights above the surface plate, and at equal distances from the front rail, by means of the relative eccentric rollers, each pair equally turned.

8. Repeat from 3, in case of disturbance from 7.

9. Adjust upper rollers to a height $f$ (111·5 mm. in the first model) above the centre rollers, by bringing the latter vertically under the first and measuring their vertical distance with the help of the internal and external micrometer gauges.

10. To set bottom rollers, which are the hinges of the rules, a horizontal distance $f$ from the top rollers place two parallel bars across the bridge to support a precision square, slide the square against the rule, clamp the rule in its vertical position to the top tie bar of the instrument, measure the

distance of the edge of the rule from the centre of the roller and adjust the cross slide of the lower pivot for the discrepancy from $f$. Repeat.

11. Centre a réseau plate, cut down to lantern-plate size, on each of the plate stages. For this, clamp horizontally in a bench vice the carriage assembly from which the backing of the circle has been removed for greater freedom in turning, mount a micrometer microscope approximately above the centre of the circle, and centre the middle cross of the réseau by turning the circle 180°, taking half the displacement of the cross with the stops and half with the micrometer mark, until coincidence is retained in both positions. Repeat for a diameter of the circle 90° from the first. Clamp the stops and replace the carriage assembly on the bridge.

12. Adjustment of collimation. Both mirror carriers having been taken off, centre each lens successively by making the middle crosses of the réseau coincide when the one is projected on the other through the lens.

13. Measure the distance between the two extension collars of the lenses when set for minimum base by clipping two small glass plates against the collars, measuring the interval with the inside micrometer gauge and adding the thickness of the glass plates. For the first model to which all the measures which follow refer, the result was $152{\cdot}30 + 5{\cdot}05 = 157{\cdot}35$ mm.

14. Compute data for any arbitrary setting of the machine. For $f = 111{\cdot}50$ mm., at magnification 3, $f_1 = 446{\cdot}20$ and $f_2 = 148{\cdot}667$ mm.

15. Adjust roller of extension bar of left carriage to a height $f_1 - 2f = 223{\cdot}200$ mm. above the bottom roller, after the height scale of the latter has been set to its zero of 5·00 mm. Then adjust bottom roller of the right rule 223·200 mm. below the roller of the extension bar of the right carriage. Note the reading of the height screw, which has to be reproduced later.

16. Replace mirror holders. Projecting images of réseaux on a sheet of white paper placed on the surface plate and covered with a third réseau plate, raise or lower the surface plate into approximate focus and level it.

17. Adjust the inclination of each mirror by means of its levelling screws until the projected image of the middle cross remains stationary for all heights of the bridge.

18. Turn the height screw until the magnification of the image projected on the surface plate réseau becomes 3 for the right-hand system. Take the mean reading of a number of observations, and setting the screw at this mean and the small micrometer of the left mirror slide at its zero of 5·00 mm., turn the adjusting screw of the micrometer stop until the magnification of the left system is also 3, from a number of observations.

19. The distance between the projected crosses of the two réseaux is the length of the minimum base. To measure this distance, set a division of the surface plate réseau in coincidence with the projected cross of the

right plate and measure with the small micrometer the distance of the nearest division from the projected cross of the left réseau. The mean reading on a division 70 mm. from the first was 6·51 mm. The zero being at 5·00 mm., the length of the base is $70+5{\cdot}00-6{\cdot}51=68{\cdot}49$ mm.

20. Determination of horizontal portions $s_a$ and $s_b$ of $f_1$ (fig. 2):

| | |
|---|---|
| Left lens (No. 63) $f$ – extension | 5·6 mm. |
| Nodal interval | 1·9 ,, |
| Right lens (No. 62) $f$ – extension | 5·7 ,, |
| Nodal interval | 1·9 ,, |
| Total | 15·1 mm. |

The front nodal points of the lenses are therefore 15·1 mm. nearer together than the seats of the collars of the lenses. Their distance apart is then $157{\cdot}35-15{\cdot}1=142{\cdot}25$ mm. The minimum base being 68·49 mm., $s_a+s_b$ is $142{\cdot}25-68{\cdot}49=73{\cdot}76$ mm., and, having been made equal by using the same magnification, $s_a=s_b=36{\cdot}88$ mm.

21. To measure the height of the middle roller above the optical axis, place the levelling square on the surface plate and the inside micrometer with its base on the square and measure successively the height of the roller and the height of the bottom of the circle above the square.

| | | | |
|---|---|---|---|
| Roller above square | 238·330 mm. | Circle above square | 85·070 mm. |
| Radius of roller | 9·525 ,, | Radius of circle | 71·440 ,, |
| | 227·855 mm. | | 156·510 mm. |

Difference 71·345 mm. Mean of two measures 71·340 mm.

22. Adjustment of surface plate to focus. The surface plate should be lowered $2f-s_a$, plus the measure of 21, below the level of the bottom roller, that is $223{\cdot}000-36{\cdot}88+71{\cdot}340=257{\cdot}460$ mm. From an approximate setting, the difference in level was measured by packing on the surface plate the following:—

| | | | |
|---|---|---|---|
| Precision square | 199·685 mm. | Rule to roller casing | 19·470 mm. |
| Parallel No. 2 | 50·292 ,, | Roller casing | 3·120 ,, |
| Precision rule | 39·891 ,, | Radius roller | 9·525 ,, |
| | +289·868 mm. | | –32·115 mm. |

$289{\cdot}868-32{\cdot}115=257{\cdot}753$ mm. is then the height of the bottom roller above the surface plate. The plane of the projected picture, which may be the surface of a sheet of paper, or that of a target, should therefore be $257{\cdot}753-257{\cdot}460=0{\cdot}293$ mm. above the surface plate. The setting of the

surface plate was, however, not altered pending the fitting of a micrometer head to one of the footscrews, which will allow of the adjustment being completed more accurately and varied as required without repeating the whole measurement which involves some dismantling.

23. Adjustment of plate holders to focus. We had $f_2 = 148{\cdot}667$ mm. from the computed data of 14. The height screw being turned back to the reading at which $f_1 - 2f$ was 223·30 mm. (15), we have

| | | |
|---|---|---|
| Right system . | $f = 111{\cdot}50$ mm. | $f_2 = 148{\cdot}667$ mm. |
| Extension . | 105·80 ,, | 5·700 ,, |
| Difference . | 5·70 mm. | 142·967 mm. |

Set, by means of the stop screw on the extension bar, the plane of the plate 142·967 mm. from the plane of the extension collar, both having been defined by clipped glass plates.

| | | |
|---|---|---|
| Left system . | $f = 111{\cdot}50$ mm. | $f_2 = 148{\cdot}667$ mm. |
| Extension . | 105·90 ,, | 5·600 ,, |
| Difference . | 5·60 mm. | 143·067 mm. |

Proceed as for the right plate.

The five settings that have to be made to adjust the instrument are shown, in fig. 7, by thick lines marked I, II, III, IV, and V, and the measurements necessary for their determination by figures against thin lines.

*Height Scale.*—Let $Z$ be the height of a point, in mm. on the map scale, $p$ the principal distance of the diapositives that are projected, and $f$ the focal length of the projection lens. We have

$$\frac{Z}{p} = \frac{f_1}{f_2} = \frac{f_1 - f}{f},$$

$$Z = \frac{p}{f}(f_1 - f).$$

If we set the height screw to read $R = f_1 - f$ we get

$$Z = \frac{pR}{f} = \frac{75}{111{\cdot}5}R = 0{\cdot}6726R.$$

The constancy of the nodal points from which $f_1$, $f_2$, and $f$ are reckoned is absolute in a theoretical lens only, and it is far better to establish the values of these from ratios $f_1/f_2 = m$, which can be measured very accurately with the help of astronomical réseau plates. The derived value of $f$ and the zero for $f_1$ are then those which correspond best with observations within the range of the machine. It has not seemed necessary to alter the

adjustments previously made to make them correspond with this effective value of $f$ because they remain sufficient to secure sharp definition at all

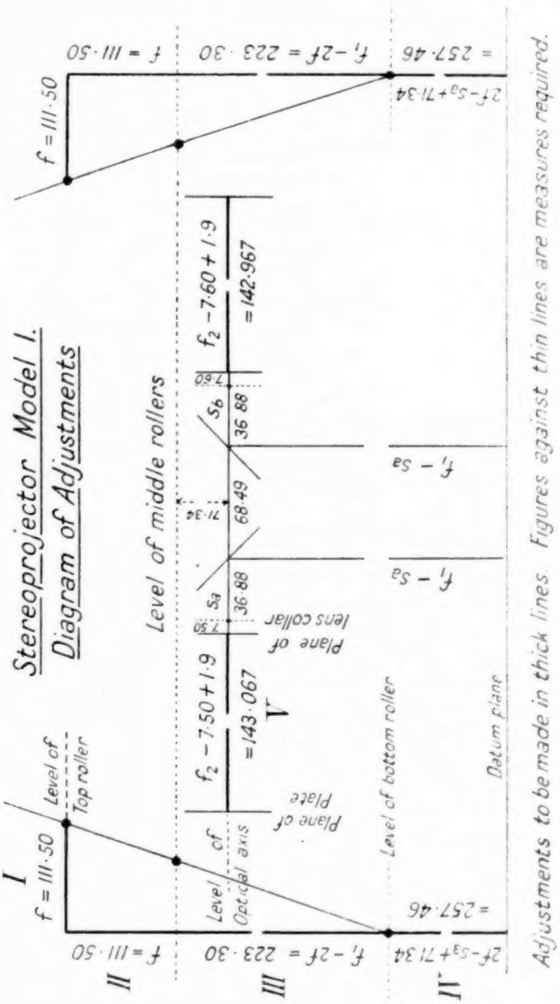



Fig. 7.

magnifications and, as will be seen, to ensure the sufficient constancy of the variation of $m$ with height.

In carrying out these determinations the image of the réseau plate, cut down to lantern size, is projected upon a sheet of white paper laid on the surface plate beneath a full-sized réseau which is a square grid of 12 cm. sides divided into 5 mm. squares, which must necessarily be viewed through the glass, thereby raising the virtual image plane above the plane of the réseau.

The coincidence of $n$ divisions of the projected scale having been established upon end, or other, divisions $X$ of the receiving scale (fig. 8) the path of the projecting ray is $CPX$, with $OX = 6$ cm. If there were no glass the receiving scale would have to be placed at $O'X' = OX$ to meet the ray $CP$ and make $f_1$ the distance of the plane of $O'X'$ from the projecting centre $C$.

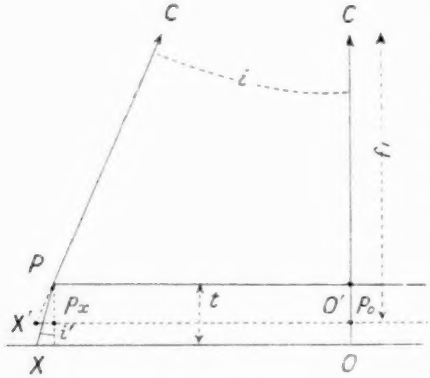



FIG. 8.

The condition making $O'X' = OX$ is that $p_x \tan i = t \tan i'$, $i'$ being given by $\sin i' = \sin i / \mu$, whence

$$p_x = \frac{t}{\mu} \cdot \frac{\cos i}{\cos i'}.$$

Computation for magnifications 2 and 3 and the outer divisions of the réseau gives $p_x = 0{\cdot}991t/\mu$ for the first and $p_x = 0{\cdot}995t/\mu$ for the second. With a mean value of 0·993 for the coefficient, and taking $\mu = 1{\cdot}515$ for crown glass we get $p_x = 0{\cdot}655t$, or, reckoning from the surface of the réseau, $t - p_x = 0{\cdot}345t$. The thickness of the réseau plate used was 1·48 mm. For it, therefore, $t - p_x = 0{\cdot}510$ mm.

Another small correction results if the image is projected on a plane at a height differing slightly from the established datum.

Changing $f_1$ to $f_1' = f_1 - \Delta f_1$, without altering $f_2$, $f_1' = f'(1 + m')$, where $m' = f_1'/f_2$.

To restore magnification $m$

$$f_1'' = f'(1 + m),$$

and the lens must be raised

$$\Delta R = f_1'' - f_1' = f'(m - m'),$$

or, $m - m'$ being very small,

$$\Delta R = f(m - m')$$

$$= \frac{f}{f_2} \Delta f_1.$$

But $$f_2 = f(1 + 1/m),$$

and $$\Delta R = \frac{m}{m+1}\Delta f_1.$$

By 22, the datum plane was found to be 0·293 mm. above the surface plate. The addition of a sheet of paper 0·085 mm. thick and of a réseau for which $t - p_x = 0{\cdot}510$ mm. will raise the receiving plane 0·595 − 0·293 = 0·302 mm. above the datum plane, so that $\Delta R = 0{\cdot}302m/m+1$. The observed readings (means of 10) of the height screw for various magnifications, the corrections from the expression just given, and the corrected readings were:

| | | | | |
|---|---|---|---|---|
| Magnification . | 3·5/1 | 3/1 | 2·5/1 | 2/1 |
| Mean reading . | 225·764 | 170·217 | 114·690 | 59·073 |
| Correction . . | −0·235 | −0·227 | −0·216 | −0·202 |
| | 225·529 | 169·990 | 114·474 | 58·871 |

From $f_1 = R + C = f(1 + f_1/f_2)$ we get the equations

$$\begin{aligned} 225{\cdot}529 + C &= 4{\cdot}5A, \\ 169{\cdot}990 + C &= 4{\cdot}0A, \\ 114{\cdot}474 + C &= 3{\cdot}5A, \\ 58{\cdot}871 + C &= 3{\cdot}0A, \end{aligned}$$

which give for the most probable values of $A$ and $C$

$$A = 111{\cdot}095 \text{ mm.}, \qquad C = 274{\cdot}389.$$

Replacing these values in the observation equations we get

$$\begin{aligned} 499{\cdot}92 &= 4{\cdot}5A + 0{\cdot}00 \text{ mm.} \\ 444{\cdot}38 &= 4{\cdot}0A - 0{\cdot}01 \quad ,, \\ 388{\cdot}86 &= 3{\cdot}5A - 0{\cdot}03 \quad ,, \\ 333{\cdot}26 &= 3{\cdot}0A + 0{\cdot}03 \quad ,, \end{aligned}$$

The largest difference is less than 1 in 10,000 of $f_1$.

The constancy of the ratio between the distance of the projecting centre and the magnification of the projected picture is the necessary and sufficient condition for the accurate working of the instrument. All the movements are but means for that end. The relation has been shown to be very approximately linear, which is a remarkable result, seeing that it is dependent on freedom of the lens from distortion, the figure of the mirror, accuracy of the screws and movements, substantial correctness of the adjustments, and inconsiderable errors of observation.

The accuracy is due to the fact that the diapositive is constrained

mechanically, by a device owing its precision to its simplicity, to remain constantly in that conjugate focus of the target which would apply to a geometrically perfect lens, and the depth of focus of the physical lens, which, on account of diffraction due to the wave nature of light, is greater actually than geometrically, is sufficient to preserve the sharpness of the pictures at all mechanically determined conjugate distances. Again, the pencil of rays from the projecting lenses is restricted to a field of only about 15° from the centre over which distortion is negligible.

But it must be borne in mind that the instrument, however perfect, can only give out what is put into it. The correctness of the results obtained will be limited by that of the photographs used. In film cameras provided with a pressure plate, there is considerable distortion from refraction through the glass. Its effect can be largely reduced, but not completely eliminated, by using a similar pressure plate in the rectifying camera and by adopting a value of the principal focus, which makes the distortion a minimum over the field.

It is possible to avoid this source of error by fitting the pressure plate at the back of the film instead of in front, or by suitably correcting the lenses, or by using glass plates instead of films. The subject will be discussed in fuller detail when the rectifying camera has been completed and described.

The two lenses not being quite identical there may remain a small discrepancy between $R_a'$ and $R_b'$ at magnification $m'$, after $R_a$ and $R_b$, the readings on the height scale for the left- and right-hand lenses at magnification $m$ have been made equal by adjustment of the mirror slide. It may be removed by altering $f_{1b}$ and $f_{2b}$, which are disponible within the limits set by the depth of focus of the lenses, so as to place the nodal points of the left lens at the same height as those of the right lens.

$R_a$ and $R_b$ having been made equal,

$$\begin{aligned} f_a &= (R_a - R_a')/(m - m'), \\ f_b &= (R_a - R_b')/(m - m'), \quad (R_a = R_b), \\ f_{1a}' &= f_a(1 + m), \\ f_{1b} &= f_b(1 + m), \\ D &= f_{1b} - f_{1a} = \frac{R_a' - R_b'}{m - m'}(1 + m). \end{aligned}$$

Set $f_{1b} = f_{1a}$ by deducting $D$ on the mirror slide, then set $f_{2b}$ to restore magnification $m$. $f_{2b}$ should then remain equal to $f_{2a}$ at all heights, since they are further altered by similar mechanical constraints on either side.

The discrepancy between the value of the effective focus $A$ and that of $f$ determined by physical methods for the lens is not significant because the value $A$ applies only to a particular setting of the datum plane and could be

altered considerably by using another setting. At the same time there probably is a real difference in the positions of the nodal points with varying magnification, but its effect becomes merged in the relation between projection distance and magnification within the limits of the instrument.

From the effective focal length the formula for the height scale, previously given, now becomes

$$Z = \frac{p}{f}(f_1 - f) = 0{\cdot}67510(R + 163{\cdot}293)$$

and

$$R + 163{\cdot}294 = 1{\cdot}48127Z.$$

The first figure of $R$ is not indicated by the counter, but an error of 100 mm. can scarcely be made, as that would be misjudging the height of the air station by 4400 ft. when the scale is 1/20,000 and by even more on smaller scales.

For contouring, successive intervals of 100 m. and 100 ft. will be given by

| Scale. | 100 m. | 100 ft. | For difference of 1 mm. in screw readings. | |
|---|---|---|---|---|
| | mm. | mm. | m. | ft. |
| 1/10,000 | 14·813 | 4·515 | 6·75 | 22·1 |
| 1/15,000 | 9·875 | 3·010 | 10·13 | 33·2 |
| 1/20,000 | 7·406 | 2·257 | 13·50 | 44·3 |
| 1/25,000 | 5·925 | 1·806 | 16·88 | 55·4 |
| 1/50,000 | 2·963 | 0·903 | 33·75 | 110·7 |

When, for the determination of tilts, the base is made 100 mm. the scale of projection for a height of 15,000 ft. = 4572 m. and an overlap of 60 per cent. is 1/18,288, a sufficiently open scale to afford good measurements of the disparities in the correspondence of points.

*Adjustment of Stops.*—The réseaux, having served their turn, are removed from the plate stages when a standard template is substituted of which the centre mark is centred as was the réseau. The stops are then clamped permanently, their setting screws taken out and the reference marks of the plate holder adjusted to agree with those of the template.

## V. Relative Tilts of a Pair of Air Photographs. Derivation of Formulæ.

The disposition of co-ordinate axes is made determinate if we assume clockwise rotations to be positive, in conformity with the graduation of circles and the reckoning of bearings (fig. 9).

In fig. 10, $O_1O_2$, being two air stations, take $O_1O_2$ as the positive direction of the $x$-axis.

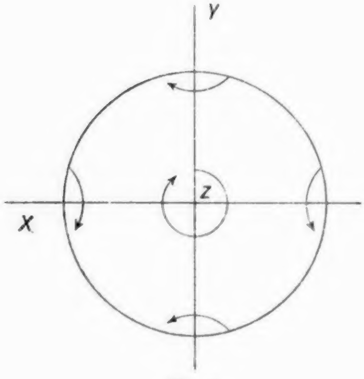



Fig. 9.

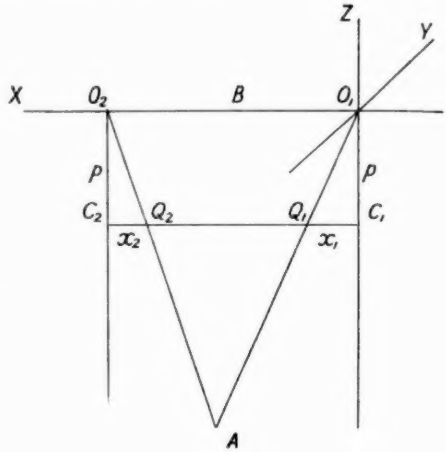



Fig. 10.

The plate co-ordinates of $Q_1$ are

$$x_1y_1 \text{ (origin } C_1),$$

those of $Q_2$ are

$$x_2y_2 \text{ (origin } C_2),$$

$$O_1O_2 = B; \qquad x_1 - x_2 = e; \qquad y_1 = y_2.$$

The co-ordinates of $A$ are then

$$Z = -\frac{B}{e}p,$$

$$X_1 = \frac{B}{e}x_1; \qquad X_2 = \frac{B}{e}x_2,$$

$$Y = \frac{B}{e}y.$$

It is to be noted that the relations hold for $B$, $X_1$, $X_2$, $Y$, and $Z$ on any other common scale, which may suitably be the map scale, or the scale of the diagram plotted by the instrument from a pair of plates. It follows that in any formula obtained in terms of $e$, $x$, $y$, and $p$, the ratio of any pair of the first may be substituted for the ratio of the corresponding pair of the second. Thus $\frac{Z}{B}$ for $-\frac{p}{e}$, etc. Also, that $X_1 - X_2 = \frac{B}{e}(x_1 - x_2) = B$.

Give the plate $C_1$ (fig. 11) a small positive fore-and-aft tilt $\theta_1$ about $O_1 Y$. Then

$$x_1 = p \tan \alpha,$$
$$x_1' = p \tan (\alpha + \theta_1)$$
$$= p \tan \alpha + \frac{p}{\cos^2 \alpha} \theta_1$$
$$= p \tan \alpha + p\theta_1 (1 + \tan^2 \alpha),$$

and $\Delta e = \Delta x_1 = p\theta_1 \left(1 + \frac{x_1^2}{p^2}\right)$ (origin $C_1'$).

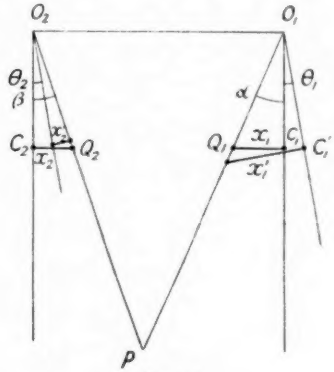



FIG. 11.

Similarly, a small positive fore-and-aft tilt $\theta_2$ of plate $C_2$ about $O_2 Y$ gives

$$\Delta x_2 = p\theta_2 \left(1 + \frac{x_2^2}{p^2}\right) \text{ (origin } C_2')$$
$$\Delta e = -\Delta x_2.$$

For the change in $Y$ we have (fig. 12)

$$\frac{y_1}{y_1'} = \frac{O_1 a}{O_1 b} = \frac{p/\cos \alpha}{p/\cos(\alpha + \theta_1)} = \frac{\cos(\alpha + \theta_1)}{\cos \alpha}$$
$$= \cos \theta_1 - \sin \theta_1 \tan \alpha.$$

$\theta_1$ being a small angle,

$$\frac{y_1}{y_1'} = 1 - \theta_1 \tan \alpha,$$
$$y_1' = y_1 \left(1 + \frac{x_1}{p_1} \theta_1\right).$$
$$\Delta y_1 = \frac{x_1 y_1}{p} \theta_1.$$

Similarly,

$$\Delta y_2 = \frac{x_2 y_2}{p} \theta_2.$$

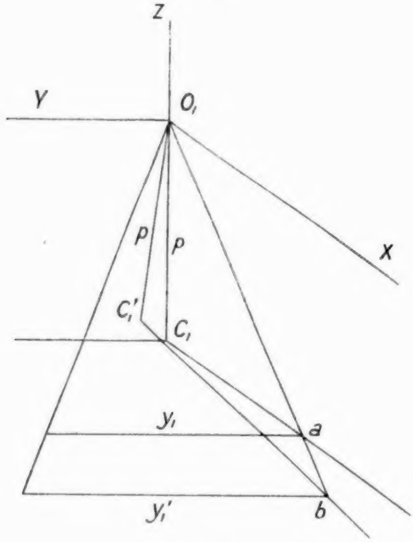



Fig. 12.

It may be useful at this stage to realise the extent of the limitations of differential formulæ to small tilts. They may be considered sufficiently accurate for tilts under 30′, which are practicable when the flying is done with an automatic pilot, but their error increases nearly as the square of the tilt. Thus for a value of $\tan a = 1/2{\cdot}5$ resulting from a 60 per cent. overlap and $X = B$, the approximate formula $\frac{\Delta y}{y} = \theta \tan a$ is correct to $\theta/136$, or 7″, when $\theta = 15'$. The corresponding figures for other tilts are

| | | |
|---|---|---|
| Tilt 30′ | Residual error | $\theta/69 = 26''$. |
| ,, 1° | ,, ,, | $\theta/35 = 1'\ 43''$. |
| ,, 2° | ,, ,, | $\theta/17{\cdot}9 = 6'\ 42''$. |

When tilts exceed 45′ their determination would, therefore, be better made in a stereogoniometer.

*Cross Tilts* (*about x-axis*).—Positive tilt $\phi_1$ (fig. 13). ($\phi$ in figure should be $\phi_1$.)

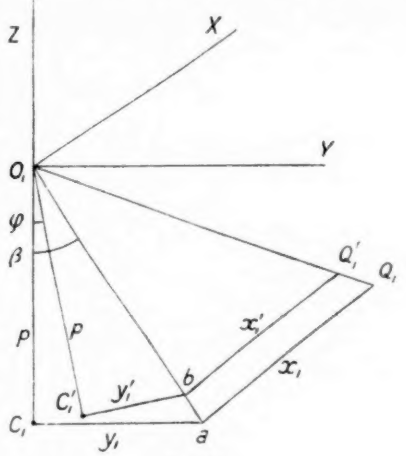



FIG. 13.

$$y_1 = p \tan \beta,$$

$$\begin{aligned} y_1' &= p \tan (\beta - \phi_1) \\ &= y_1 - \frac{p}{\cos^2 \beta}\phi_1 \\ &= y_1 - p\phi_1(1 + \tan^2 \beta) \\ &= y_1 - \left(p + \frac{y_1^2}{p}\right)\phi_1. \end{aligned}$$

$$\Delta y_1 = -p\phi_1\left(1 + \frac{y_1^2}{p^2}\right),$$

$$\begin{aligned} \frac{x_1}{x_1'} &= \frac{O_1a}{O_1b} = \frac{p/\cos \beta}{p/\cos (\beta - \phi_1)} = \frac{\cos (\beta - \phi_1)}{\cos \beta} \\ &= \frac{\cos \beta + \phi_1 \sin \beta}{\cos \beta} \\ &= 1 + \phi_1 \tan \beta, \end{aligned}$$

$$x_1' = x_1 - \frac{x_1 y_1}{p}\phi_1,$$

$$\Delta x_1 = -\frac{x_1 y_1}{p}\phi_1.$$

Similarly,

$$\Delta y_2 = -p\phi_2\left(1 + \frac{y_2^2}{p^2}\right),$$

$$\Delta x_2 = -\frac{x_2 y_2}{p}\phi_2.$$

By taking the principal point base $C_1'C_2$ in fig. 14 for $x$-axis of the plate co-ordinates, a rotation $\lambda$ about $C_2Z$ is given to the $x$-axis $C_1C_2$ to which

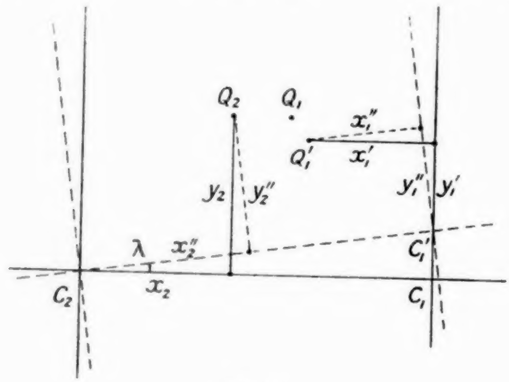



Fig. 14.

the co-ordinates $x_1'y_1'$ of $Q_1'$ and $x_2y_2$ of $Q_2$ were referred. $b = C_1C_2$ being the distance between the two principal points

$$\lambda = \frac{C_1C_1'}{C_1C_2} = \frac{p\phi_1}{b},$$

the co-ordinates becoming

$$y_2'' = y_2 + x_2\frac{p\phi_1}{b},$$

$$x_2'' = x_2 - y_2\frac{p\phi_1}{b},$$

$$y_1'' = y_1' + x_1'\frac{p\phi_1}{b} = y_1' + \frac{x_1 p\phi_1}{b} - \frac{x_1y_1}{b}\phi_1^2,$$

$$x_1'' = x_1' - y_1'\frac{p\phi_1}{b} = x_1' - y_1\frac{p\phi_1}{b} + \left(p + \frac{y_1^2}{p}\right)\frac{p\phi_1^2}{b}.$$

Dropping the terms in $\phi^2$ we have, for small tilts, sufficiently,

$$y_1'' = y_1 - p\phi_1 - \frac{y_1^2}{p}\phi_1 + \frac{x_1 p}{b}\phi_1,$$

$$x_1'' = x_1 - \frac{x_1y_1}{p}\phi_1 - \frac{y_1 p}{b}\phi_1,$$

and since $y_1 = y_2$

$$y_2'' - y_1'' = p\phi_1 + \frac{y_1^2}{p}\phi_1 - \frac{x_1 - x_2}{b}p\phi_1.$$

$$x_1'' - x_2'' = x_1 - x_2 - \frac{x_1 y_1}{p}\phi_1.$$

$$\Delta e = -\frac{x_1 y_1}{p}\phi_1.$$

Similarly, for a positive tilt $\phi_2$ of Plate 2, we get

$$y_1'' - y_2'' = p\phi_2 + \frac{y_2^2}{p}\phi_2 - (x_1 - x_2)\frac{p\phi_2}{b},$$

$$x_1'' - x_2'' = x_1 - x_2 + \frac{x_1 y_1}{p}\phi_2,$$

$$\Delta e = +\frac{x_2 y_2}{p}\phi_2.$$

Substituting in the formulæ $X_1$ for $x_1$, $X_2 = B - X_1$ for $x_2$, $-Z$ for $p$, and $Y_1$, $Y_2$ for $y_1$, $y_2$ we arrive at the general expressions for the increments $\Delta Y$ due to tilts $\theta$ and $\phi$

$$\Delta_1 Y = -\frac{XY}{Z}\theta,$$

$$\Delta_2 Y = \frac{Y^2}{Z}\phi.$$

From the foregoing we get on the $Y$-axis of Plate 1, putting $\phi$ for $\phi_2 - \phi_1$

$$D_1 = Y_1' - Y_1 = \frac{BY_1}{Z_1}\theta_2 + \frac{Y_1^2}{Z_1}\phi,$$

$$D_4 = Y_4' - Y_4 = \frac{BY_1}{Z_4}\theta_2 + \frac{Y_4^2}{Z_4}\phi,$$

and on the $Y$-axis of Plate 2

$$D_2 = Y_2' - Y_2 = -\frac{BY_2}{Z_2}\theta_1 + \frac{Y_2^2}{Z_2}\phi,$$

$$D_3 = Y_3' - Y_3 = -\frac{BY_3}{Z_3}\theta_1 + \frac{Y_3^2}{Z_3}\phi.$$

These effects of tilts $\theta_1$, $\theta_2$, $\phi_1$ and $\phi_2$ on the correspondence of points are shown diagramatically in fig. 15.

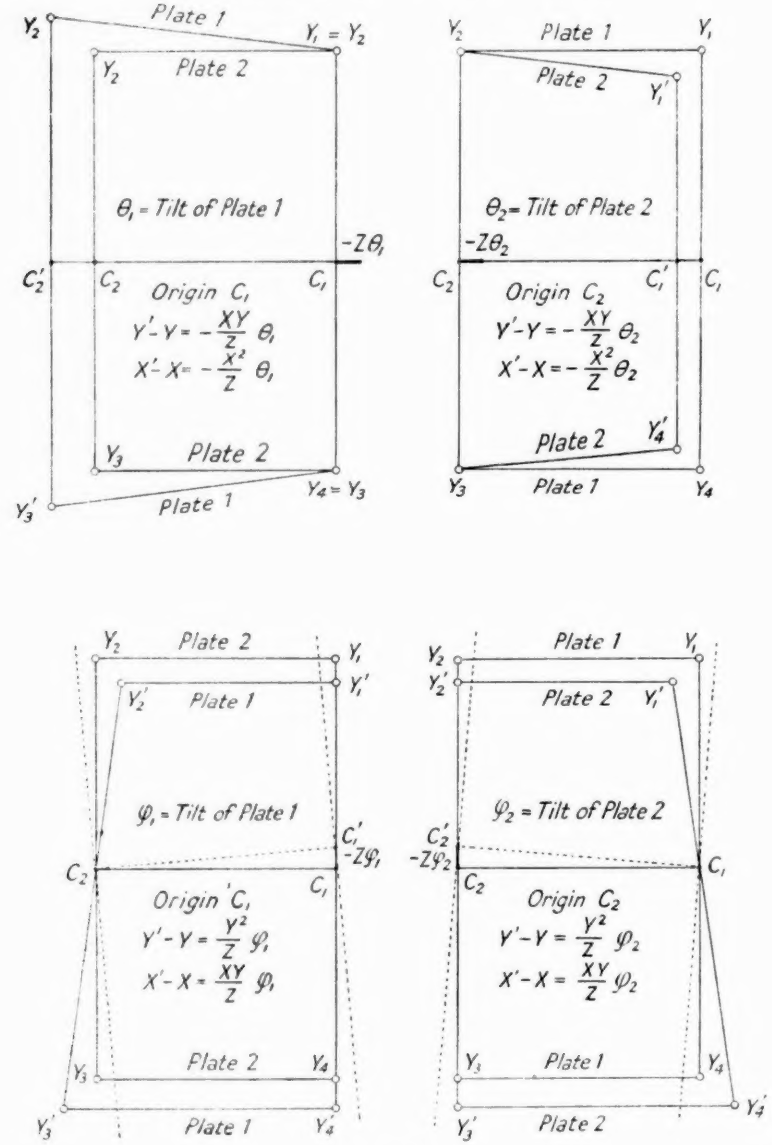


Plate 1
Plate 2
Y'_1 = Y_2
θ_1 = Tilt of Plate 1
-Zθ_1
Origin C_1
Y'-Y = -XY/Z θ_1
X'-X = -X²/Z θ_1
Plate 2
Plate 1
Y_4 = Y_3
θ_2 = Tilt of Plate 2
-Zθ_2
Origin C_2
Y'-Y = -XY/Z θ_2
X'-X = -X²/Z θ_2
φ_1 = Tilt of Plate 1
-Zφ_1
Origin C_1
Y'-Y = Y²/Z φ_1
X'-X = XY/Z φ_1
φ_2 = Tilt of Plate 2
-Zφ_2
Origin C_2
Y'-Y = Y²/Z φ_2
X'-X = XY/Z φ_2

FIG. 15.

Any marks intersected by the $Y$-axes will serve for points, no knowledge of their positions or character being needed.

Set $B = 100$ mm. $Z$ is not given directly by the height scale of the instrument of which the reading is $R = -kZ$, $k$ being a constant, for the particular instrument, obtained as explained elsewhere. In the first model $k = 1{\cdot}4867$.

The equations are then of the form

$$D = \frac{100Y}{Z}\theta + \frac{Y^2}{Z}\phi,$$

or

$$\frac{DZ}{Y} = 100\theta + Y\phi.$$

Substituting $-\frac{R}{k}$ for $Z$ and taking $R$ and $Y$ in decimetres and $D$ in millimetres, we have

$$\frac{DR}{100kY} = \theta + Y\phi.$$

For $\theta$ and $\phi$ in minutes of arc this becomes

$$\frac{34{\cdot}38}{kY} = \theta + Y\phi,$$

or with the value of $k$ for the particular instrument

$$-\frac{23{\cdot}10}{Y}DR = \theta + Y\phi.$$

Putting

$$a = -\frac{23{\cdot}10 D_1 R_1}{Y_1}, \quad b = -\frac{23{\cdot}10 D_2 R_2}{Y_2}kC,$$

we have, finally,

$$\begin{aligned} a &= \theta_2 + Y_1\phi, \\ b &= -\theta_1 + Y_2\phi, \\ c &= -\theta_1 + Y_3\phi, \\ d &= \theta_2 + Y_4\phi. \end{aligned}$$

Three of the equations are sufficient to determine the unknowns, but it is better and equally simple to use all four.

The least square treatment of the equations yields

$$\begin{aligned} \phi &= \frac{(Y_1 - Y_4)(a-d) + (Y_2 - Y_3)(b-c)}{(Y_1 - Y_4)^2 + (Y_2 - Y_3)^2}, \\ 2\theta_1 &= (Y_2 - Y_3)\phi - (b+c), \\ 2\theta_2 &= (a+d) - (Y_1 + Y_4)\phi. \end{aligned}$$

The measures of $R$ and $Y$ are influenced by the tilts, but for small tilts their approximation will be sufficient for the determination of $\theta$ and $\phi$ within an accuracy limited by the errors of measurement of $D$ or $R$.

In order to get some idea of the accuracy feasible in determining relative tilts, take points $Y_1$, $Y_2$, $Y_3$ and $Y_4$ at respective distances from $C_1$ and $C_2$ equal to $C_1C_2$, and an overlap of 60 per cent. Then flying at 4000 m. the scale of the projected image is for a base of 100 mm. 1/16,000, $R = 2{\cdot}5 \times 1{\cdot}4867 = 3{\cdot}72$; $a_1 = -23{\cdot}1 \times 3{\cdot}72 D_1 = -86 D_1$ and in minutes of arc

$$\phi = \frac{a + b - c - d}{4}.$$

If the p.e. of $D_1$ is $\pm 0{\cdot}01$ mm., that of $a$ is $\pm 0{\cdot}01 \times 86 = \pm 0{\cdot}9$, and the p.e. of $\phi$ $\pm 0{\cdot}9/2 = \pm 0{\cdot}4'$.

We have also

$$2\theta_1 = -(b + c),$$
$$2\theta_2 = a + d,$$
$$\theta_2 - \theta_1 = \frac{a + b + c + d}{2},$$

of which the p.e. $= \pm 0{\cdot}8'$.

In suitable floating marks a probable error in $D$, within $\pm 0{\cdot}01$ mm. is attainable with sharp photography, the average of several observers then giving a p.e. of $\pm 0{\cdot}005$ for the mean of 5 bisections, but, of course, larger errors may arise from uneliminated instrumental errors, inadequacy of differential formulæ for considerable tilts and other causes.

## VI. Application of the Tilt Formulæ.

### A. *Determination of the Relative Tilts of a Pair of Plates from the Correspondence of Points.*

$C_1C_2$ (fig. 16) is the principal point base of a pair of photographs, and

$$D_1 = Y_1' - Y, \qquad D_2 = Y_2' - Y_2,$$
$$D_3 = Y_3' - Y_3, \qquad D_4 = Y_4' - Y_4,$$

are the disparities in correspondence of marks, on the photographs, which are intersected by the $y$-axes of $C_1$ and $C_2$. $C_1C_2$ being the positive direction of the $x$-axes, let $\theta_1\theta_2$ be the fore-and-aft tilts of $C_1$ and $C_2$ along the $x$-axes and $\phi_1\phi_2$ their cross-tilts along their respective $y$-axes. The relative tilts are $\theta = \theta_2 - \theta_1$, and $\phi = \phi_2 - \phi_1$.

Set the instrument to a base of 100 mm. Bring $C_2$ and $C_1$ into correspondence by rotating the plate of $C_1$ until its image of $C_2$ lies on the $x$-axis $C_1C_2$, and rotating the plate of $C_2$ until its image of $C_1$ is also upon the same

axis. By means of the height screw, $C_1$ and its corresponding point and $C_2$ and its corresponding point are brought successively into coincidence.

Keeping the base as 100 mm. draw, with the instrument, a diagram of the $x$- and $y$-axes and the positions on the latter of the four $Y$-marks of which the disparities $D$ are measured, with the sine micrometer already

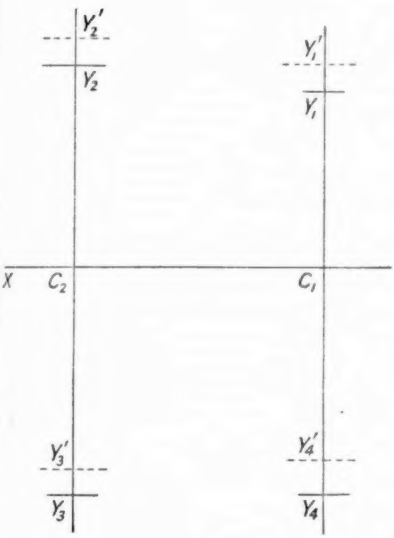



Fig. 16.

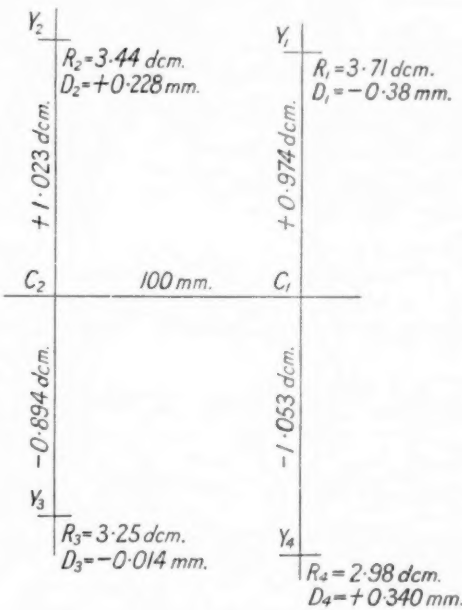



Fig. 17.

described, and recorded on the diagram, together with the co-ordinates $Y_1 Y_2 Y_3$ and $Y_4$ measured graphically on the diagram. The direction of the plate axes of $C_1$ and $C_2$ is also traced by the instrument on the diagram, and, lastly, the readings $R_1 R_2 R_3 R_4$ and the disparities $D_1 D_2 D_3 D_4$ entered.

*Example.*—Fig. 17 represents the diagram, from a pair of plates $C_1$ and $C_2$, on which the measures of $Y_1 Y_2 Y_3 Y_4$ and the readings $R_1 R_2 R_3 R_4$ and $D_1 D_2 D_3 D_4$ are entered.

The expressions for $abc$ and $d$ were

$$a = -\frac{23 \cdot 10 D_1 R_1}{Y_1},$$

$$b = -\frac{23{\cdot}10D_2R_2}{Y_2},$$

$$c = -\frac{23{\cdot}10D_3R_3}{Y_3},$$

$$d = -\frac{23{\cdot}10D_4R_4}{Y_4}.$$

*Computation* (by slide rule):

| | | | | | |
|---|---|---|---|---|---|
| $a = +\ 3{\cdot}36$ | $Y_1 - Y_4$ | $+\ 2{\cdot}027$ | $(Y_1 - Y_4)^2$ | $4{\cdot}12$ |
| $b = -17{\cdot}60$ | $Y_2 - Y_3$ | $+\ 1{\cdot}917$ | $(Y_2 - Y_3)^2$ | $3{\cdot}68$ |
| $c = -\ 1{\cdot}37$ | $a - d$ | $-18{\cdot}84$ | | |
| $d = +22{\cdot}30$ | $b - c$ | $-16{\cdot}23$ | | $7{\cdot}80$ |

$(Y_1 - Y_4)(a - d)$ $\quad -38{\cdot}30$

$(Y_2 - Y_3)(b - c)$ $\quad -31{\cdot}20$ $\qquad \phi = \dfrac{-69{\cdot}50}{7{\cdot}80} = -8{\cdot}9'.$

$\qquad -69{\cdot}50$

| | |
|---|---|
| $(Y_2 + Y_3)\phi = -0{\cdot}129 \times 8{\cdot}9 = -\ 1{\cdot}15$ | $-(Y_1 + Y_4)\phi = -0{\cdot}079 \times 8{\cdot}9 = -\ 0{\cdot}70$ |
| $-(b + c) = +18{\cdot}97$ | $(a + d) = +25{\cdot}56$ |
| $\theta_1 = +8{\cdot}9'$ $\quad 2\theta_1 = +17{\cdot}82$ | $\theta_2 = +12{\cdot}4'$ $\quad 2\theta_2 = +24{\cdot}86$ |

### B. *Connection of First Pair with Ground Control.*

The relative tilts of the first pair having been determined, the pair is rectified to a common plane, the heights of the control points, on the scale of the diagram, are read on the instrument, and their co-ordinates measured on the diagram.

Let $P_1P_2P_5$ (fig. 18) be three of the control points. $H_3$ is the height of $P_3$ above that of $P_1$ reduced to the scale of the diagram, and $H_5$ the height of $P_5$ above $P_1$. $H_3'$ and $H_5'$ are the corresponding heights read on the instrument. Put $h_3 = H_3 - H_3'$ and $h_5 = H_5 - H_5'$, and call $\theta$ and $\phi$ the corrections to the tilts $\theta_1$, $\theta_2$, $\phi_1 = 0$, and $(\phi_2 - \phi_1) = \phi_2$ which were used in rectifying Plates 1 and 2. The co-ordinates $y_3x_3$ and $y_5x_5$ of $P_3$ and $P_5$, with $P_1$ as origin, having been measured graphically on the diagram, we get

$$y_3\phi - x_3\theta = h_3,$$
$$y_5\phi - x_5\theta = h_5,$$

giving $\phi$ and $\theta$.

*Example.*—Using the data given in fig. 18, which are:

| | *y.* | *x.* | *h.* |
|---|---|---|---|
| $P_1$ . | 0·00 | 0·00 | 0·00 |
| $P_3$ | $-\ 87{\cdot}2$ | 81·2 | $-0{\cdot}002$ |
| $P_5$ | $-192{\cdot}7$ | $-19{\cdot}4$ | $-0{\cdot}475$ |

the resulting equations are

$$-\ 87{\cdot}2\phi+81{\cdot}2\theta=-0{\cdot}002,$$
$$-192{\cdot}7\phi+19{\cdot}4\theta=-0{\cdot}475,$$

giving, on a slide-rule computation,

$$\theta=-1/422=-8{\cdot}1', \qquad \phi=1/434=+7{\cdot}8'.$$

If the relative tilts of the first pair are those of the example previously given, the final absolute tilts will be:

| | | |
|---|---|---|
| Plate 1, | $\theta_1=+0{\cdot}8'$, | $\phi_1=+7{\cdot}8'$, |
| Plate 2, | $\theta_2=+4{\cdot}3'$, | $\phi_2=-1{\cdot}1'$. |

The last pair of a strip is similarly connected with ground-control points.

When there are more than three control points, a graphical solution may be made, or else a least-square adjustment.

*Graphical Solution.*—The co-ordinates measured graphically on the diagram (fig. 18), plotted by the machine, of the control points and the

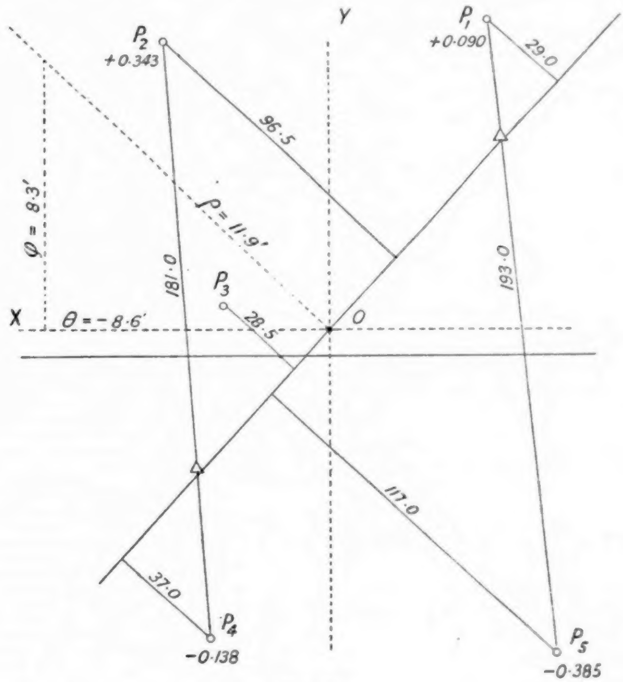



FIG. 18.

axes of the first pair of plates, with the principal point of Plate 1 as origin, are, in mm.,

| | $y$. | $x$. | $h$. |
|---|---|---|---|
| $P_1$ | 102·3 | 9·2 | 0·000 |
| $P_2$ | 95·1 | 108·4 | +0·253 |
| $P_3$ | 15·1 | 90·4 | −0·002 |
| $P_4$ | −85·2 | 95·1 | −0·228 |
| $P_5$ | −90·4 | −10·2 | −0·475 |
| | +215·5 | +303·1 | +0·253 |
| | −175·6 | −10·2 | −0·705 |
| Sum | +36·9 | +292·9 | −0·452 |
| Mean | +7·4 | +58·6 | −0·090 |

Reduced to mean origin $O$:

| | | | |
|---|---|---|---|
| $P_1$ | +94·9 | −49·4 | +0·090 |
| $P_2$ | +87·7 | +49·8 | +0·343 |
| $P_3$ | +7·7 | +31·8 | +0·088 |
| $P_4$ | −92·6 | +36·5 | −0·138 |
| $P_5$ | −97·8 | −68·8 | −0·385 |

$\theta$ and $\phi$ are then the tilts of the plane containing $O$ and fitting best $h_1 \ldots h_5$. $A$ point, on this plane, for which $h=0$ is given by any pair of the control points. Thus from $P_1$ and $P_5$ a point along $P_1P_5$ of length 193·0 mm. measured on the diagram, for which $h=0$ is found at a distance from $P_1$ given by

$$l=\frac{0{\cdot}090\times 193{\cdot}0}{0{\cdot}385+0{\cdot}090}=36{\cdot}7 \text{ mm. by slide rule,}$$

and along $P_2P_4$ of length 181·6 mm., another point for which

$$l=\frac{0{\cdot}343\times 181{\cdot}0}{0{\cdot}343+0{\cdot}138}=128{\cdot}7.$$

The other pairs of points are not as well conditioned, positions for which $h=0$ being too near the mean origin $O$ through which the line of no tilt must pass, or else have to be obtained by extrapolation. Draw then the line $MN$, through $O$, and fitting best the two zeros plotted, and next perpendiculars $p_1 \ldots p_5$ on $MN$ from each of the points $P_1 \ldots P_5$. Calling $\rho$ the tilt of the plane about $MN$ we should have

$$p_1\rho=h_1, \qquad p_2\rho=h_2, \text{ etc.}$$

Measuring $p_1 \ldots p_5$ on the diagram, we get

| | | | | | | |
|---|---|---|---|---|---|---|
| $p_1$ | 29·0 | $h_1$ +0·090 | | $p_4$ | −117·0 | $h_4$ −0·385 |
| $p_2$ | 96·5 | $h_2$ +0·343 | | $p_5$ | −37·0 | $h_5$ −0·138 |
| $p_3$ | 28·5 | $h_3$ +0·088 | | | −154·0$\rho$ = | −0·523 |
| | 154·0$\rho$ = | +0·521 | | | | |

Whence mean $\rho=1/295=+11{\cdot}9'$.

Draw, through $O$, a perpendicular to $MN$ and set off, on any convenient scale and in the positive direction of $h$, $OR=\rho$. The co-ordinates of $R$ give $\phi$ and $\theta$ graphically, $OX$ being the negative direction of $\theta$, we get

$$y=\phi=+8{\cdot}3',$$
$$-x=\theta=-8{\cdot}6'.$$

*Least Square Adjustment.*—Owing to the simple form of the equations, a least square adjustment is, perhaps, even easier than a graphical one, if a slide-rule and a table of squares are used.

From the co-ordinates and values of $h$ reduced to mean origin $O$ we get equations

$$y_1\phi-x_1\theta=h_1,$$
$$y_2\phi-x_2\theta=h_2,$$
$$\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot$$

$$\left.\begin{aligned}\Sigma(y^2)\phi-\Sigma(xy)\theta&=\Sigma(yh)\\ -\Sigma(xy)\phi+\Sigma(x^2)\theta&=-\Sigma(xh)\end{aligned}\right\}\text{ or }\left\{\begin{aligned}A\phi-C\theta&=D.\\ -C\phi+D\theta&=-E.\end{aligned}\right.$$

$$\theta=\frac{CD-AE}{AB-C^2}.\qquad\phi=\frac{BD-CE}{AB-C^2}.$$

*Example.*—Computation from the data of fig. 18 is as follows:—

| | $y^2$. | $x^2$. | $xy$. | $yh$. | $xh$. |
|---|---|---|---|---|---|
| $P_1$ | 9006 | 2440 | − 4680 | + 8·5 | − 4·4 |
| $P_2$ | 7691 | 2480 | + 4370 | +30·0 | +17·1 |
| $P_3$ | 59 | 1011 | + 245 | + 0·7 | + 2·8 |
| $P_4$ | 8575 | 1332 | − 3380 | +12·8 | − 5·0 |
| $P_5$ | 9565 | 4733 | + 6730 | +37·7 | +26·5 |
| | 34896 | 11996 | +11345 | +89·7 | +46·4 |
| | | | − 8060 | | − 9·4 |
| | | | + 3285 | | +37·0 |
| | $A$ | $B$ | $C$ | $D$ | $E$ |

| | | |
|---|---|---|
| $CD=+$ 294 000 | $AB=+418\,000\,000$ | $BD=+1\,078\,000$ |
| $-AE=-1\,290\,000$ | $-C^2=-$ 10 800 000 | $-CE=-$ 121 500 |
| − 996 000 | +407 200 000 | + 956 500 |

$$\theta=-1/408=-8{\cdot}4'.\qquad\phi=+1/425=+8{\cdot}1'.$$

As before, these tilts have to be added to the relative tilts of each of the first pair.

*Correction for Curvature.*—The relative tilts of a pair of plates are independent of the curvature of the earth and also of small differences in height of the two stations. Referred to their separate verticals, the relative tilt $\theta=\theta_2-\theta_1$ is decreased by 0·545′ for each 1000 m. of the principal

point base when proceeding in the direction $+X$. If the flight is fairly straight, the effect on the transverse tilts $\phi$ need not be considered.

Proceeding from the initial fore-and-aft tilt of the first plate as determined by the ground control, the successive tilts and corrections for curvature are added until we reach the terminal plate of which the actual tilt is also determined by ground control. A discrepancy $C-O=\Delta\theta$ is found between the computed and observed values of the terminal tilt. It is eliminated by adding, if there are $n$ stations, corrections $-\dfrac{\Delta\theta}{n-2}$ to each intermediate $\theta$. And similarly with $\phi$s.

Actually, it is not necessary to compute the curvature corrections separately. It is equally accurate, if the air stations are at approximately equal distances apart, to include the corrections in the closure corrections.

*Addition of Tilts.*—Before tilts can be added together, they must be reduced to a common orientation. Suitably, the axes may be those of the

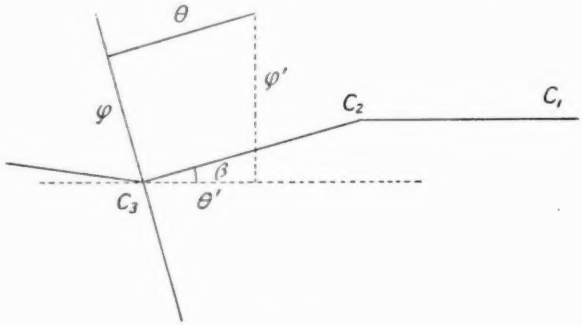



FIG. 19.

first pair $C_1C_2$ (fig. 19). Then, if $\theta$ and $\phi$ are the fore-and-aft and cross-tilts of a plate, relative to the preceding one, and $\beta$ the rotation of the axes required to make them parallel to those of the first pair, the rectified partial tilts will be

$$\theta'=\theta\cos\beta-\phi\sin\beta,$$
$$\phi'=\phi\cos\beta+\theta\sin\beta,$$

or, $\beta$ being a small angle,

$$\theta'=\theta-\phi\sin\beta,$$
$$\phi'=\phi+\theta\sin\beta.$$

The deviations are measured on a tracing, piecing together the diagrams of each plate pair, by means of the common plate-axes of consecutive pairs. When, as shown below, the final values of $\theta$ and $\phi$ are established

for each plate, they are plotted on the tracing, giving at once, for each plate, the total tilt $\rho$ and its direction $a$, reckoned from the positive direction of the $x$-axis of the plate.

In the example which follows, the absolute tilts of the first and last plates, and the relative tilts of every consecutive pair, have been computed by the methods already given.

| | 1. Tilts referred to first base. 2. Relative tilts of following plate. $\theta$. | $\phi$. | 1. Deviation $\beta$. 2. sin $\beta$. | 1. Relative tilts $\theta$. 2. Corr. for deviat. $-\phi \sin \beta$. | $\phi$. $+\theta \sin \beta$. | 1. Correction for closure and curvature. 2. Corrected tilts. | | 1. Angles of direction $a$. 2. Tilts $\rho$. |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | − 8·4′ | + 8·1′ | 0 | .. | .. | 0 | | 48° 30′ |
| | + 3·5 | − 8·9 | 0 | .. | .. | − 8·4′ | + 8·1′ | 11·0′ |
| $C_2$ | − 4·9 | − 0·8 | +7° 40′ | +12·5 | −19·0 | + 2·0 | − 0·85 | 354° 0′ |
| | +15·0 | −17·3 | +0·1334 | + 2·5 | + 1·7 | − 2·9 | − 1·6 | 3·4 |
| $C_3$ | +10·1 | −18·1 | +3° 0′ | + 1·0 | −21·9 | + 4·0 | − 1·7 | 217° 0′ |
| | + 0·1 | −21·9 | +0·0523 | + 1·1 | 0·0 | +14·1 | −19·8 | 21·2 |
| $C_4$ | +10·2 | −39·0 | −3° 30′ | +16·4 | +36·9 | + 6·0 | − 2·55 | 253° 0′ |
| | +18·6 | +35·9 | −0·0610 | + 2·2 | − 1·0 | +16·2 | −36·5 | 39·8 |
| $C_5$ | +28·8 | − 3·1 | +2° 30′ | + 0·9 | −28·6 | + 8·0 | − 3·40 | 187° 10′ |
| | + 2·1 | −28·6 | +0·0436 | + 1·2 | 0·0 | +36·8 | − 6·5 | 43·4 |
| Computed $C_6$ | +30·9 | −31·7 | Corr. to interm. plates | | | + 8·0 | − 3·40 | 288° 10′ |
| Observed | +39·0 | −35·1 | $\frac{+8\cdot1}{n-2} = +2\cdot0$ | $\frac{-3\cdot4}{n-2} = -0\cdot85$ | | +38·9 | −35·1 | 51·7 |
| $C-O$ | − 8·1 | − 3·4 | | | | | | |

There will be less liability to error in the signs of $\phi \sin \beta$ and $\theta \sin \beta$ if a small table is made use of. $\beta$ in the table is the deviation of the first base from the direction of the base considered.

*Table of Signs.*

| $\beta$. | $\theta$. | $\phi$. | $-\phi \sin \beta$. | $+\theta \sin \beta$. |
|---|---|---|---|---|
| + | + | + | − | + |
| + | + | − | + | + |
| + | − | + | − | − |
| + | − | − | + | − |
| − | + | + | + | − |
| − | + | − | − | − |
| − | − | + | + | + |
| − | − | − | − | + |

For example, on the line of $C_3$, above, $\beta = +3° \ 0'$, $\theta = -1\cdot0$, and $\phi = -21\cdot9$ are given consecutively. Reference to the table shows that, for this order of signs, the signs of the corrections are + and −.

*Graphical Addition of Tilts.*—A graphical solution, represented by fig. 20, in which the deviations are purposely exaggerated for the sake of clearness,

suggests itself. $Y_1O_1$, $Y_2O_2$, $Y_3O_3$, etc., are the $y$-axes of Plates 1, 2, 3, etc. $Y_2O_2$ is common to the two diagrams, traced by the machine, of the relative positions of the principal point bases and the plate co-ordinates, for the pairs 1–2 and 2–3. $Y_3O_3$ is common to the pairs 2–3 and 3–4, and so on. The initial absolute tilts $\theta_1$ and $\phi_1$ are plotted, on any sufficiently large scale, as co-ordinates with origin $O_1$ and the principal point base $O_1O_2$ as

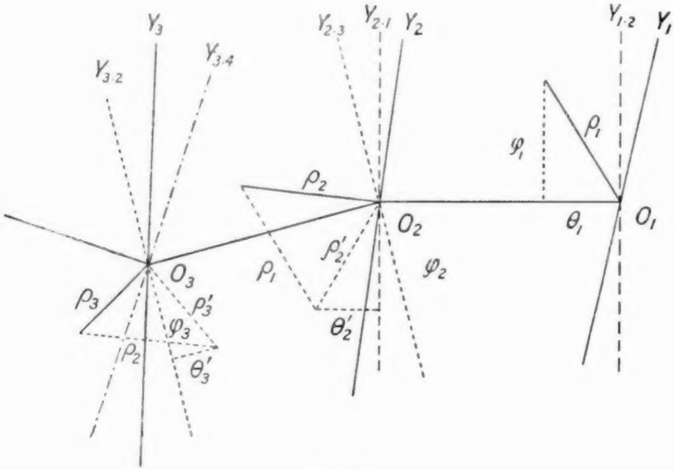



FIG. 20.

$x$-axis, and the tilts $\theta_n'$ and $\phi_n$ of each plate relatively to the preceding one also plotted with the principal point $O_n$ as origin and the principal point base $O_{n-1}O_n$ as $x$-axis. The resultant vectors $\rho_n'$ are drawn, after which they are successively added together graphically, beginning from that of Plate 1. The discrepancy $C-O$, at the close of the traverse, between the final values of $\theta$ and $\phi$ obtained graphically and those determined independently for the last plate, are distributed, as in the numerical example, along the $\theta'$ and $\phi$ lengths for each plate, the vectors $\rho'$ redrawn, and again added graphically together. To avoid confusion the corrected and uncorrected vectors may be drawn in inks of different colour.

## VII. ERRORS RESULTING FROM TILTS.

1. *Errors in Heights.*—From $Z = -\dfrac{B}{e}f$ we get

$$dZ = \frac{Bf}{e^2}de - \frac{f}{e}dB.$$

If a fore-and-aft tilt $\theta_1$ is given to Plate 1, Plate 2 being provisionally considered level, in accordance with the principle of the independence of

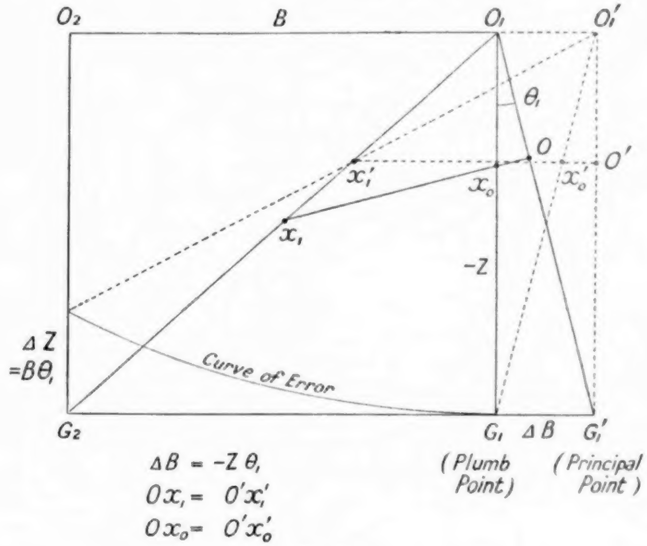



FIG. 21.

small effects, and the plate perpendicular $O_1O$ (fig. 21) of Plate 1 taken as the vertical, the actual base becomes $G_2G_1' = B - Z_a\theta_1$, where $Z_a$ is the $Z$-co-ordinate of the point $G_1$ at which $O_1O$ meets the ground, this point becoming one end of the "principal point base."

So now, due to tilt $\theta_1$,

$$\Delta Z = \frac{Bf}{e^2} f\theta_1\left(1 + \frac{x_1^2}{f^2}\right) + \frac{f}{e} Z_a\theta_1$$

$$= \frac{B\theta_1}{e^2}(f^2 + x^2) + \frac{f}{e} Z_a\theta_1.$$

When $e = B$,

$$\text{(1)} \qquad \Delta Z = \frac{\theta_1}{B}(Z^2 + X_1^2) - \frac{ZZ_a}{B}\theta_1$$

$$= \frac{X_1^2}{B}\theta_1 + \frac{Zh_a}{B}\theta_1,$$

in which $h_a = (Z - Z_a)$ or, more accurately, when the tilts are not very small,

$$\Delta Z = \left( Z + \frac{X_1^2}{B}\theta_1 \right) \frac{B - Z_a\theta_1}{B - Z\theta_1} - Z.$$

Similarly from a tilt $\theta_2$ of Plate 2,

$$(2) \qquad \Delta Z = \frac{X_2^2}{B}\theta_2 + \frac{Zh_b}{B}\theta_2.$$

From the lateral tilts $\phi_1$ and $\phi_2$, for which $\Delta e = -\frac{xy}{f}\phi$, and $B$ remains unchanged, we have, further,

$$(3) \qquad \Delta Z = -\frac{Bx_1y}{e^2}\phi_1 = -\frac{X_1Y}{B}\phi_1.$$

$$(4) \qquad \Delta Z = -\frac{X_2Y}{B}\phi_2.$$

The total error in $Z$ will then be the sum of (1), (2), (3) and (4).

The region mapped from one pair of plates will extend longitudinally to the principal points, and, laterally, to $Y$-distances about equal to the base. It may be seen from the above partial expressions that, when $\Delta Z$ (1) is a maximum for $X_1 = Y = B$, $\Delta Z$ (2) becomes zero. Also, when $\Delta Z$ (3) is a maximum for $X_1 = Y = B$, $\Delta Z$ (4) is also zero. Further, since $\rho^2 = \theta^2 + \phi^2$ where $\rho$ is the greatest tilt, $\Delta Z$ will be a maximum for $\theta = \phi = \rho/\sqrt{2}$, with $X_1 = -Y = B$. Then

$$\Delta Z = 2B\theta_1 + \frac{Zh}{B}\theta_1,$$

approximately.

*Example.*—$Z_a$ is $-10{,}000$ ft., $B = 4000$ ft., $\rho = 3°$. $Z\theta_1$ is then $2\rho/\sqrt{2} = 4°\ 15'$. For a point $X_1 = -Y_1 = B$, on the level of $Z_a$, the maximum error may be

$$\Delta Z = \frac{2\rho}{\sqrt{2}}B = 297{\cdot}3 \text{ ft.}$$

For smaller tilts with the same data

| | | | |
|---|---|---|---|
| 2° | 139·7 ft. | 130·8 ft. | 147·7 ft. |
| 15′ | 17·5 ,, | 16·5 ,, | 18·5 ,, |
| 1′ | 1·2 ,, | 1·2 ,, | 1·2 ,, |

The influence of the second term $\frac{Zh}{B}\theta_1$ is greatest when $\theta_1 = \rho$, making $\phi$ zero. Then for a point $X = B$, $Y = O$, on the level of $Z_a$,

$$\Delta Z = B\theta_1 = +209{\cdot}6 \text{ ft.}$$

For a point 100 ft. above $Z_a$, $Z = -9900$ ft. and, from the approximate formula $\Delta Z = +196{\cdot}6$ ft., or 198·3 ft. from the more accurate working.

For smaller tilts, maximum errors $\Delta Z$ are

| Tilt. | $Z = Za$. | $Z - Za = +100$ ft. | $Z - Za = +100$ ft. |
|---|---|---|---|
| 2° | 139·7 ft. | 130·8 ft. | 147·7 ft. |
| 15′ | 17·5 ,, | 16·5 ,, | 18·5 ,, |
| 1′ | 1·2 ,, | 1·2 ,, | 1·2 ,, |

The proportional error, from tilts, of the difference in height of two points has sometimes been wrongly assumed to be the same as the proportional error in the $Z$-height of a point. From the above it will be seen that for a tilt $\theta_1$ of 3°, the height of the foot of a tree, itself 100 ft. high, on a level plain 10,000 ft. below the air base may be 209·6 ft. in error and the height of its top 198·3 ft. in error, giving a resulting height for the tree of 88·7 ft. or 11·3 per cent. in error, instead of the 2·1 per cent. error. With tilts of 15′ the maximum error in the height of the tree would be reduced to 1 ft.

2. *Errors in Y-co-ordinates.*—Similarly, the error in the $Y$-co-ordinate will be greatest when $\phi = \theta = \rho/\sqrt{2}$. Then

$$\frac{\Delta Y}{Y} = \frac{2Y}{Z}\frac{\rho}{\sqrt{2}}.$$

For $Y = B$, and a 60 per cent. overlap, $Z = 2{\cdot}5B$,

$$\frac{\Delta Y}{Y} = \frac{\sqrt{2}}{2{\cdot}5}\rho = 0{\cdot}565\rho.$$

3. *Errors in X-co-ordinates.*—For $X$, the maximum error would also be

$$\frac{\Delta X}{X} = \frac{2Y}{Z}\frac{\rho}{\sqrt{2}},$$

and for the same case as last,

$$\frac{\Delta X}{X} = 0{\cdot}565\rho.$$

Flying at 15,000 ft., $B = 6000$ ft. for an overlap of 60 per cent. Then, for $Y = B$, the maximum error in either the $Z$ or the $Y$-co-ordinate would be 15 ft. = 4·5 m., when $\rho = 15'$. On a scale of 1/50000 it would be 0·1 mm., but the average error would be much less, because the average $\rho$ is then probably less than two-thirds of 15′ and the average $X$ or $Y$ only one-half of $B$.

It is therefore apparent that, as far as tilts are concerned, if the exposures are made from a gyro-controlled aeroplane, kept level within 15′, the

planimetry could be constructed, for small scales, without rectification of the negatives, while contour lines could also be drawn if enough spot heights are provided to control the lines here and there.

## VIII. Determination of Tilts with the Stereogoniometer.

The Stereogoniometer gives directly the relative longitudinal and cross-tilts of a pair of plates set in correspondence. Further, it is not then necessary, as it is with the stereoprojector alone, to make an intermediate rectification, to a common plane, of a pair of terminal plates. The co-ordinates of control points are readily obtained, referred to the plane containing the air base and at right angles to the plane containing both the air base and the principal axis of the plate for which $\lambda = 0$. From an assumed base, we have for the co-ordinates of any point $C$, $A$ and $B$ being the angles which $AC$ and $BC$ make with the air base.*

$$x = M \cot A,$$
$$y = M \sin \lambda,$$
$$z = -M \cos \lambda,$$

where

$$M = \frac{b \sin A \sin B}{\sin (A + B)}.$$

The determination of the absolute tilts of the plates may then proceed exactly as with stereoprojector reductions.

When the tilts are large, as in the case of obliques, they may be computed by the methods detailed in the author's previous papers on the stereogoniometer, already referred to, but it is simpler to make first an approximate rectification of the obliques to verticals, of which the tilts are then determined and added to those used in making the intermediate rectification.

The lantern plates used for the rectifications should be made with two adjacent edges ground to slightly rounded surfaces, indicated readily by blunting their common corner. The plates can then be clipped against accurately similar stops in the rectifying camera, the stereogoniometer or the stereoprojector, without any manual setting to the reference marks being necessary. This automatic setting increases the precision of the work and saves a great deal of time.

## IX. Summary of Procedure.

1. The film negatives are reduced in the camera, without rectification but corrected for variation in the focal length of the lens of the air camera

* Trans. Roy. Soc. S. Afr., vol. 14, p. 100 (1926).

and average shrinkage of the film, to a constant principal distance $p$. If a stereogoniometer taking lantern plates is used for the determination of tilts, $p$ becomes the principal distance, made common by setting, of its two lenses. This value of $p$, which should be within 1 or 2 mm. of 75, is then retained in computing the coefficient of the height screw of the stereoprojector.

2. Successive pairs of the reduced diapositives are inserted in the machine and their principal points set in correspondence by turning one of the circles, then the other.

3. A diagram is drawn for each pair, by the machine, showing the orientation of the plate axes relatively to the principal point axes.

4. If a stereogoniometer is not available, the disparities of four pairs of points on the principal $y$-axes are measured and noted on the diagram. The fore-and-aft tilt $\theta$ and the cross-tilt $\phi$ of the forward plate relatively to the back plate are computed by slide-rule. If a stereogoniometer is available, the two plates are set in correspondence and $\theta$ and $\phi$ measured directly on the circles of the instrument.

5. The $\theta$ and $\phi$ of each plate are plotted as co-ordinates, taking the principal point as origin and the principal point base from the preceding plate as $x$-axis.

6. The absolute tilts of the first and last plates of a strip are determined by reference to ground control, either in the stereoprojector or the stereogoniometer. For the first plate this is best done when it is still in either machine.

7. The tilts are added together graphically and the discrepancy between the computed and observed values of the tilts of the last plate distributed equally among the partial tilts of the intermediate plates. These corrected tilts are then added up again graphically.

8. The tilts of each negative now being known, rectified diapositives can be made from them.

9. The first pair of rectified diapositives having been inserted in the stereoprojector, with Plate 1 on the right, a map is drawn to any specified scale within the limits of the machine. The planimetry is first drawn and then the contour lines. If the two air stations were not at the same height, pairs of points distant from the $x$-axis will not be in correspondence. In this case alter the height of the projection centre of the left picture by turning by equal amounts the micrometer of the mirror slide and that of the slide of the bottom roller until correspondence of all pairs of points is established. Note the reading on the height screw of definite points on that portion of the overlap common to Plates 1, 2, and 3.

10. Repeat with Plates 2 and 3 the procedure restoring correspondence when their air stations differ in height. Note again on the height screw the readings of the definite points that were observed on Plates 1 and 2.

The proportion by which the new readings differ from the old, both reckoned from the zero of the screw, will be the proportion by which the old base should be altered to give the new. To change the length of the base turn equally the micrometer altering the separation of the lenses, and the micrometer altering the effective length of the extension bar. The length of the base is that of the minimum base, plus the length of the standard rods inserted, plus the reading of the separating micrometer. Draw the map of the overlap of Plates 2 and 3.

11. Proceed similarly with every remaining pair of plates.

12. The separate overlaps, having all been mapped on the same scale, can now be joined together by transfer on a sheet of tracing paper.

## X. Acknowledgments.

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Since construction of the first model, that of two more instruments of a second model was begun, under my supervision, at the Survey Workshop, Mowbray, which is well equipped with precision machinery, and they are now nearing completion. On this work Mr. L. V. Holmgren, assisted by Messrs. T. R. Miller and R. C. Hampton, both exceptionally skilled instrument-makers, has been engaged. As before, the heavy parts were made by the General Engine and Boiler Company, of London, but the trueing and scraping of their guiding surfaces was done at Mowbray, where also were constructed all the smaller mechanical parts previously made in England. The lenses were again supplied by Messrs. Ross & Co., Ltd., to special accuracy and special rollers by Messrs. Hoffmann. Messrs. Adam Hilger, Ltd., supplied the reflectors which were aluminised in place of being silvered. Otherwise Model II is identical with Model I, no improvements having suggested themselves from the operation of the completed instrument. Only a few minor alterations in dimensions were made to provide better clearance at points.

A precision rectifying camera to work in conjunction with the stereo-projectors is also being built at Mowbray, to the author's designs.

Cape Town,
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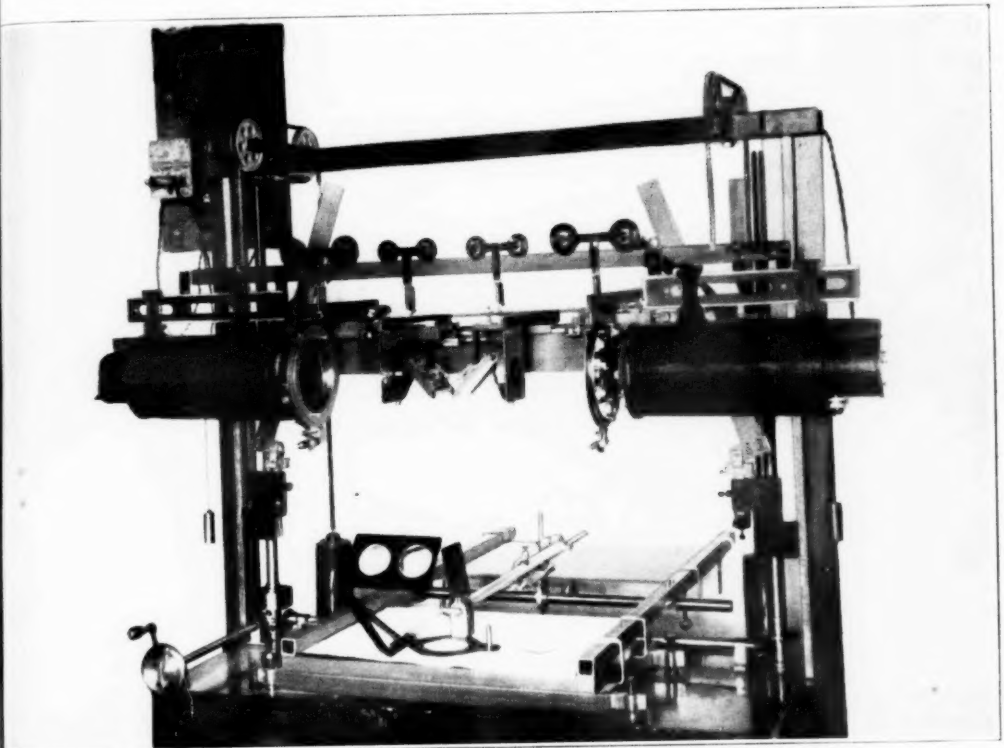

H. G. Fourcade.

Neill & Co., Ltd.